The ecology and conservation of bryophytes in Tasmanian wet eucalypt forest

Perpetua A. M. Turner B.Sc. (Hons)

Submitted in fulfilment of the requirements of the degree of

Doctor of Philosophy

School of Geography and Environmental Studies

University of Tasmania

Hobart

July 2003

Declaration

This thesis contains no material that has been accepted for the award of any other degree or diploma in any tertiary institution and, to the best of my knowledge and belief, the thesis contains no material previously published or written by another person, except where due reference is made in the text.

Perpetua A.M. Turner (nee Blanks)

11th July 2003

Authority of Access

This thesis may be made available for loan. Copying of any part of this thesis is prohibited for two years from the date this statement was signed; after that time limited copying is permitted in accordance with the Copyright Act 1968.

Perpetua A.M. Turner (nee Blanks)

11th July 2003

Abstract

The aim of this study was to determine the factors that affect bryophyte richness and species composition in wet eucalypt forest, including old growth and forest disturbed by wildfire or silvicultural practice.

Approximately one third of the total bryophyte flora for Tasmania was recorded in old growth mixed forest, with more liverwort than moss species found. Bryophyte species composition was significantly different between groups of sites of forest from the northwest, central and southern areas of the state. Mean annual temperature, altitude, rainfall of the driest month and aspect were most significant in predicting variation in bryophyte species composition.

The use of vascular plants as surrogates for the conservation of bryophyte species was examined. Vascular plant and fern species richness were significant but poor predictors of bryophyte species richness. A minimum set of 31 sites reserved all vascular species and a large percentage (82.9%) of bryophyte species at least once. Thus, reserves selected using vascular plants are likely to reserve a large proportion of bryophyte species. The reserve sets included more sites of regenerating forest than old growth forest indicating the importance for conservation of multi-aged wet eucalypt forest.

Many species preferentially occurred on a substrate type within a particular forest age class. The bryophyte species composition on old growth *Nothofagus cunninghamii* and *Atherosperma moschatum* trees were significantly dissimilar to a large number of other substrate/age class groups. Consistent with previous literature, bark type affected species composition.

Comparisons of bryophytes in sites disturbed by wildfire and logging found four moss species occurred more frequently in logging than wildfire regeneration, whereas six of the seven bryophytes species that occurred more frequently after wildfire than logging disturbance were liverworts. Overall, little difference in bryophyte and vascular species composition was found between logging and wildfire regeneration. When sites were separated into regions, bryophyte species composition differed between logging and wildfire only in the forests of central Tasmania, where *Eucalyptus regnans* is dominant.

Successional stages of bryophytes species occurrence after disturbance were documented. Species occurring frequently in primary succession did not survive into later successional stages. Many species that established in post-primary successional forest persisted into late successional forest. Liverwort species dominated in late successional forest. The exclusive occurrence of the epiphytic mosses *Neckera pennata* and *Calyptopogon mnioides* in regenerating forest is strongly associated with the presence of *Pomaderris apetala* and *Acacia dealbata* trees.

Acknowledgements

I am indebted to my supervisors. Jamie Kirkpatrick for his enthusiasm, support, encouragement and wisdom and Emma Pharo, for her knowledge, experience, advice and for keeping me motivated.

This PhD and the move to Tasmania would not have been possible without assistance from an APA scholarship. Additional encouragement, advice and support from a number of people also facilitated the move. I thank Mark Burgman for initiating my Honours project based on bryophytes which introduced me to a fascinating new world of plants. I thank the late George A.M. Scott for his wisdom, time, patience and enthusiasm. Without his counsel I would not have seriously considered undertaking a PhD on bryophytes in Tasmania.

Mick Brown and John Hickey provided valuable logistic and technical support and taught me a great deal about forest ecology. Their advice, enthusiasm and constant encouragement greatly contributed to the project. I thank Sue Jennings for the tremendous assistance and logistic support while in the field, and for her friendship. Leigh Edwards assited in finding relevant field sites. Keely Ough provided ecological advice and much reference material.

Fieldwork would not have been possible without the assistance from Forestry Tasmania staff and Paul Smart, Darren Turner, Emma Pharo, Steve Scott, Steve Davis, Craig Weston, Frank Bishop, Rod Evans, Sandra Hetherington, Bill Tewson and Peter Ladaniwskyi. The patience and unbounded assistance given by Paul Smart is genuinely appreciated.

I am indebted to two great friends, Anita Wild and Mark Poll and the 'children', Farmy, Sal and Mush. The support, encouragement, guidance given from Anita and Mark (and licks from the 'children'!) enabled me to achieve many goals.

The amazing bryological network was always ready and willing to help at every turn. Advice and assistance were received predominantly with sampling methods and identification of difficult specimens. I am indebted to bryologists in Australia and New Zealand, in particular Dana Bergstrom, Elizabeth Brown, Judith Curnow, Paddy Dalton, Jean Jarman, Neils Klazenga, David Meagher, Pina Milne, Emma Pharo, Helen Ramsay, Rod Seppelt, Jessica Beever, Pat Brownsey, Alan Fife and David Glenny. Assitance was also gratefully received from John J. Engel (Lepidoziaceae and Geocalycaceae), Jan-Peter Frahm (*Campylopus*), Riclef Grolle (Lepidoziaceae, Lejeuneaceae), Bob Magill, Ray Tangney (*Camptochaete*) and Kohsaku Yamada (*Radula*). The assistance and advice provided by David Meagher is greatly appreciated. I am also indebted to staff of the Tasmanian Herbarium, especially Lyn Cave.

I am indebted to Leon Barmuta, Lee Belbin, Steve Candy, Richard Little, Peter Minchin and Henrik Wahren for their advice and assitance with some analyses.

Thanks to the staff and fellow 'Jamie' students of Geography and Environmental Studies. I thank Moya Kilpatrick and Pauline Harrowby for their assistance and patience. Denis Charlesworth carried out chemical analyses of soil samples. Kate Charlesworth helped find theses, articles and maps. David Somerville assisted with fieldwork equipment.

Jamie Kirkpatrick, Emma Pharo, John Hickey, Stephen Bresnehan, Anita Wild, Ljiljana Sekuljica, Sapphire M^{c}Mullan-Fisher and Rod Seppelt carried out proof reading. Anita Wild prepared the maps for the chapters. Darren Turner assisted with formatting of this thesis. Thanks especially to Anita and Sapphire for spending time checking the whole thesis.

To the Blanks family, I thank you for all your support and understanding. To Nell and Tess whose 'garden landscaping' and waggling tails never failed to bring a smile to my face when things seemed awry. Thanks also to the Turner family for your best wishes and support.

And most of all I thank Darren Thank-you for your understanding, love, patience, kindness and commitment, especially during the (many) stressful times. Without you, all this would not have been possible.

Moss Gathering. Theodore Roethke

This poem has been removed for copyright reasons

Table of Contents

Chapter Four

Chapter Five

Chapter Six

List of Figures, Tables and Appendices

Chapter One

Introduction

Bryophytes

The term 'bryophyte' refers collectively to non-vascular plants of the Divisions Bryophyta (mosses), Hepatophyta (liverworts) and Anthocerotophyta (hornworts) (Crum 2001). Hornworts and liverworts are usually considered together for convenience. Bryophytes are non-vascular, that is they lack xylem and phloem tissue. Other features include 'alternation of generations', where a photosynthetic, free-living gametophyte (haploid generation) is dominant over the simple and largely 'parasitic' sporophyte (diploid generation).

Bryophytes are major components of many ecosystems, including deserts, grassland, tropical, alpine, polar and forest (Longton 1992). Current estimates of the number of bryophyte species worldwide is approximately 25, 000 (Crum 2001). Currently the Australian bryophyte flora is estimated to consist of approximately 1100 mosses and 480 liverwort species (Scott and Bradshaw 1986; Buck *et al.* 2002), although a more recent estimate of 606 liverworts species has been made (C. Cargill pers comm. 2003). In Tasmania, the bryophyte flora consists of approximately 450 moss species (Moscal *et al.* 1997; Buck *et al.* 2002) and 300 liverwort species (Ratkowsky 1987). Although Moscal *et al.* (1997) list approximately 330 liverwort species, records upon which some of these names are based have not been completely verified. These figures are expected to increase with further research.

Bryophytes in forest ecosystems

Wet eucalypt and mixed forest

Classification of forest vegetation in Australia is primarily based on vascular plant species (Ashton and Attiwill 1994). 'Wet sclerophyll' forest was initially defined by Beadle and Costin (1952) to cover forests with an understorey of broad-leaved shrubs and/or ferns and an overstorey dominated by tall eucalypts. Wet sclerophyll forests are roughly equivalent to the 'tall open forests' of (Specht 1970) however, tall open forest is defined by structure not the understorey. Forests in Tasmania are of three main types,

temperate rainforest, wet eucalypt forest and dry sclerophyll forests (Wells and Hickey 1999). Mixed forest is defined as vegetation with a rainforest understorey and eucalypt overstorey (Gilbert 1959). The term 'wet eucalypt' forest includes both mixed forest and wet sclerophyll forest (Kirkpatrick *et al.* 1988). Wet eucalypt forests in Tasmania achieve superior growth on fertile soils and sites where rainfall is between 1000 and 1500 mm per annum (Kirkpatrick *et al.* 1988). Where there is both a reliable and high rainfall and rainfall of the driest month is greater than 50 mm (Kirkpatrick *et al.* 1988), wet eucalypt forest and mixed forest will also exist on exposed sites. In Australia, mixed forest is found in the states of Victoria, New South Wales, Queensland and Tasmania. Tasmania has the greatest extent and diversity of mixed forest. Approximately 29% of wet eucalypt forest in Tasmania is old growth or mature mixed forest, with 64% existing in reserves (Resource Planning and Development Commission 2002).

Fire in wet eucalypt forests

Fire is a natural or anthropogenic disturbance that interrupts the functioning and structure of an environment. Fire plays a fundamental role in the establishment and survival of wet eucalypt forests. Fire frequency may range from once in every 20 to once in 100 - 400 years (Mount 1979). The eucalypt overstorey of mixed forest requires fire at intervals of 100 – 400 years to regenerate, thus, in the absence of fires for more than approximately 400 years, the eucalypt overstorey dies out and rainforest will persist (Gilbert 1959; Jackson 1968). The impact of fire on wet eucalypt forest is determined by a number of factors, such as past disturbance, fuel and climate (Ashton 1981b). A substantial amount of fuel is produced via growth and litter accumulation, especially where forests exist on fertile soils and in areas higher rainfall. In conditions of dry winds and high temperatures, fires can climb into the eucalypt canopy, particularly when the area has suspended dry litter and species with fibrous bark (Ashton 1981b). Little information exists of wildfire in Tasmania prior to 1912 however wildfires are known to have occurred before and after British settlement in 1803 (Luke and McArthur 1978). Major fire seasons occurred for the years 1897 - 98, 1913 - 14, 1933 - 34, 1944 - 45, 1960 - 61 and 1966 - 67 (Luke and McArthur 1978).

Silvicultural practices in wet eucalypt forests

Timber harvesting is a major human disturbance in forests (Hansen *et al.* 1991; Attiwill 1994a). Mixed forests of Tasmania have a high wood production value. They are harvested for the production of sawlogs (*Eucalyptus* spp.) pulpwood and speciality wood products (rainforest species). The silvicultural system practiced since the 1960's in these forests has been clearfell and burn harvesting. This is currently the most commonly used method currently in Tasmania (Hickey *et al.* 2001). Clearfell and burn harvesting involves completely clearing an area of all trees in an area, usually less than 100 ha (Forest Practices Board 2000), in a single operation (Gilbert and Cunningham 1972). The remaining litter (slash, unsaleable timber, remnant understorey etc.) is burnt to create a seedbed in which regeneration of both overstorey and understorey vascular plants can occur. Revegetation of *Eucalyptus* has been undertaken by either sowing seed by hand, by aerial or naturally via remaining live trees. At present, methods primarily utilise aerial sowing (Gilbert and Cunningham 1972; Florence 1996). The interval between logging events for mixed forest is currently planned at 90 years (Whiteley 1999). The Forest Practices Board largely oversees management of forests (Forest Practices Board 2000). The Forest Practices Code provides practical guidelines for the protection of environmental values and biodiversity.

Whether or not silvicultural practice mimics natural ecological process and has similar affects on biodiversity is a much debated issue (Hansen *et al.* 1991; Attiwill 1994a; Brown 1996; Lindenmayer *et al.* 2000). If timber harvesting is to be used as a surrogate for natural disturbance (Attiwill 1994b) then verification of its suitability is required.

The effect of wildfire and logging practices on bryophytes

Much emphasis, particularly in the northern hemisphere, has been given to the ecological role of bryophytes in forests and their contribution to biodiversity, primarily as a consequence of forest management (Gustafsson and Hallingback 1988; Söderström 1988a; Franklin 1993; Frisvoll and Presto 1997; Lindenmayer and Franklin 1997; Cooper-Ellis 1998; Rambo and Muir 1998b; Hazell and Gustafsson 1999; Qian *et al.* 1999; Boudreault *et al.* 2000; Ross-Davis and Frego 2002). Pressure for the reformation of forest management practices is fundamentally a result of conservation objectives (Hansen *et al.* 1991; Franklin 1993; Hazell and Gustafsson 1999).

Similar bryophyte genera colonise early after fire and logging disturbances in both wet eucalypt and boreal forests (Duncan and Dalton 1982; Longton 1992; Johnston and Elliot 1996; Quinby 2000). Comparative studies in boreal forest have reported differences in bryophyte species composition following disturbance between areas previously burned in wildfire and those clear-cut logged (Johnston and Elliot 1996; Whittle *et al.* 1997; Nguyen-Xuan *et al.* 2000). Reich *et al.* (2001) found no indication of differing bryophyte species composition in forest stands of comparable age and forest type that originated after logging compared to after wildfire. Comparisons between clearfell burns in wet eucalypt forest (eg. Hickey 1994) and clear-cut logging in boreal forest (eg. Nguyen-Xuan *et al.* 2000; Reich *et al.* 2001) are made difficult because clear-cut methods in boreal forest are conducted mostly in winter on snow (to decrease soil disturbance) and are not always followed by regeneration burns.

Little has been conducted on the effects of wildfire or logging on bryophytes in wet eucalypt forest. Of these few studies, most have focused on post logging/burning effects on bryophyte nutrient content, bryophyte regeneration and soil chemistry (Cremer and Mount 1965; Duncan and Dalton 1982; Brasell and Mattay 1984; Brasell *et al.* 1986). Ashton (1986) provides the first major descriptive account of bryophyte communities in wet eucalypt forest after disturbance by fire. Only a single preliminary study has described bryophyte species differences between wet eucalypt forest disturbed by wildfire (old growth forest, > 110 years) and between forest disturbed by logging (Jarman and Kantvilas 1997). In comparison, studies contrasting wildfire and logging affects on vascular plants in wet eucalypt forests are numerous (Cook and Drinnan 1984; Lindenmayer *et al.* 1990b; Mueck and Peacock 1992; Ough and Ross 1992; Hickey 1994; Lindenmayer 1995; Chesterfield 1996; Ough 2001; Lindenmayer and McCarthy 2002). Ough (2001) found resprouting shrubs, tree fern and ground-fern species were more abundant in wildfire regeneration than clearfell regeneration. Hickey (1994) stated that it was unknown whether epiphytic ferns would recover within the first rotation of logging and that negative affects on filmy ferns might be representative of the possible effects on bryophytes and lichens. The initial vascular species composition following disturbance in these forests largely determines the vascular species assemblage that will dominate.

Bryophytes in old growth mixed forest

Older stands of mixed forest are termed 'old growth forest'. For the purpose of this study, this definition of old growth mixed forest will be used with the additional criteria that all old growth mixed forest is at least 110 years old without any signs of natural or man made disturbance (Commonwealth of Australia and the State of Tasmania 1996). There are many definitions of old growth forest and summaries can be found in Dyne (1991) and Resource Assessment Commission (1992).

Both aesthetic and biodiversity values of forests have been acknowledged (Franklin *et al.* 1981; Brown 1996; Burgman 1996; Norton 1996). In particular, untouched old forests have been identified as 'important reservoirs of biological diversity' (Lindenmayer and Franklin 1997). Old forests are characterised by an absence of disturbance (human or natural) for a relatively long period. Intervals extend from the last major disturbance and may range from hundreds to thousands of years (Franklin *et al.* 1981; Hansen *et al.* 1991; Scotts 1991). Bryophytes in old wet eucalypt forests of Australia have been recorded as contributing more to biodiversity than the vascular flora (Brown *et al.* 1994; Dalton *et al.* 1999). Ashton (1986) described the habitat preferences and ecological processes of bryophytes in old wet eucalypt forests of Victoria, giving the first detailed account of bryophyte ecology in old growth wet eucalypt forests. Little research has been undertaken since.

The bryophyte flora of old forests in the northern hemisphere has been recorded as species rich (Gustafsson and Hallingback 1988; Crites and Dale 1998; Vellak and Paal 1999). Rare liverworts not present in younger forests have been discovered in these older forests and ascribed as a defining feature (Gustafsson and Hallingback 1988; Crites and Dale 1998; Vellak and Paal 1999). Rambo and Muir (1998a) found that an assemblage of bryophytes, either epiphytes on conifers or liverworts on coarse woody debris indicated old-growth forest.

The importance of substrate in forests

Bryophytes inhabit a number of different substrates in forests such as trees, branches, different forms of dead wood and the ground. They play a basic key role in the ecological function of forests through moisture retention, reducing water run-off and providing habitats for other components of biodiversity (Scott 1994). Bryophytes in

temperate forests are greatest in abundance on coarse woody debris (logs, fallen branches, stumps, dead trees) and upon vascular species (Longton 1992). Bryophytes on coarse woody debris have been the focus of many studies, particularly in comparing managed and unmanaged forests (Muhle and LeBlanc 1975; Söderström 1988b; Andersson and Hytteborn 1991; McAlister 1997; Cooper-Ellis 1998; Crites and Dale 1998; Kruys and Jonsson 1999; Qian *et al.* 1999). In Europe, North America and Canada, where many forest stands are heavily managed, coarse woody debris ranges from 2.2 $m^3 ha^{-1}$in managed stands (Kruys *et al.* 1999) to 197 m^3 ha^{-1} (Linder *et al.* 1997) in old growth forests. In comparison, multiple logging rotations are rare in Tasmanian wet eucalypt forest and a sizeable volume of coarse woody debris is available for colonisation (~ 400 – 1200 m^3 ha^{-1} Forestry Tasmania unpublished data; see also McKenny and Kirkpatrick 1999). Coarse woody debris is an essential structural feature of wet eucalypt forests and a critical sanctuary for many components of biodiversity (Lindenmayer 2002).

Different properties of vascular plants such as bark pH and bark and soil chemistry affect bryophyte composition (Bates 1992; Gustafsson and Eriksson 1995). Bark properties have also been related to the bryophyte species composition on different tree species, for example Slack (1976) found where there was no change in bark properties with age, there was also no great change in epiphytic assemblages. In mature *Eucalyptus regnans* forest, Ashton (1986) studied the species composition of different substrates (tree trunks, soil patches and rocks) and topographically different areas. In eastern Australian forests, strong differences in bryophyte species composition were found between tree bases, rocks, fallen branches, ground and logs (Pharo and Beattie 2002). Research concerning bryophyte substrates in Australia also includes inventories of bryophytes on vascular plant species (Ashton and McCrae 1970; Jarman and Kantvilas 1995a; Milne and Louwhoff 1999; Jarman and Kantvilas 2001b; Roberts 2002). These studies found that many different bryophyte species occurred epiphytically on vascular plants. The survival of epiphytic bryophytes may be negatively affected by a loss of vascular substrates (Ough and Murphy 1996).

Conservation of bryophytes in forests

There is considerable concern regarding the loss of biodiversity in both old growth forest and forests of all ages (Franklin *et al.* 1981; Hansen *et al.* 1991; Franklin 1993).

Research by Franklin *et al.* (1981) in Douglas-Fir forests of northwestern North America established a number of differences between old growth and young boreal forests including structure and species composition. An extensive amount of work since has heightened the importance of biodiversity in these forests (for example see Hansen *et al.* 1991; Franklin 1993). In assessing bryophyte conservation for the future, Söderström *et al.* (1992) stressed the detrimental effect forestry practices in Sweden were having on populations of rare species such as the moss *Neckera pennata*. The authors highlighted the lack of coarse woody debris in forests due to short rotation intervals and the negative effect this was having on the persistence of epixylic, or wood specific, species. They also suggested that protection of endangered species could be achieved by creating reserves inclusive of large populations in forest of different successional stages.

In Australia, there is concern about the lack of research on non-vascular plants in wet eucalypt forests (see reviews by Burgman 1996; Norton 1996). Although, considerable progress has been made on the assessment of conservation status of bryophytes in Tasmania in all vegetation types (Brown *et al.* 1994; Moscal *et al.* 1997), habitat destruction, forestry plantations and land clearing are still prominent threats to the persistence of some species (Scott *et al.* 1997). Very little research in wet eucalypt forest includes bryophytes, (Ashton 1986; Jarman and Kantvilas 1994; Jarman and Kantvilas 1997; Jarman and Kantvilas 2001a), with even fewer studies including both bryophyte and vascular species (Blanks 1996; Turner 1996). In Tasmania, vascular flora and vertebrate fauna have played an important part in the reservation of wet eucalypt forests (Commonwealth of Australia and the State of Tasmania 1996). This is primarily because research in these forests has strongly focused on the ecology of vascular species and forest communities (Gilbert 1959; Jackson 1968; Mount 1979; Hickey 1994). Like non-vascular species, invertebrates and macrofungi have only recently received attention and are generally not considered in conservation of wet eucalypt forests (Michaels 1999; Baker 2000; Bashford *et al.* 2001; McMullan-Fisher *et al.* 2002; Packham *et al.* 2002). Under current management, it is unknown whether conservation of wet eucalypt forests based on vascular plant communities will act as a surrogate for neglected components of biodiversity, such as bryophytes.

Successional processes in forest ecosystems

The long entrenched classical view of succession (Clements 1916) has little application where disturbance, such as fire, is a regular event. Wet eucalypt forest communities after a fire disturbance generally follow the successional model of Egler (1954). In boreal forests, similar successional pathways have been described with fire also a primary disturbance feature (Heinselman 1981; Attiwill 1994a).

A number of factors may affect the ability of bryophytes to successfully establish after disturbance including severity/intensity of disturbance, competition, substrate availability (for example coarse woody debris or certain vascular species), propagule availability, plant 'vital attributes' or life histories (Noble and Slatyer 1980) and environmental conditions. In both boreal and eucalypt forest, similar bryophyte genera are found after a disturbance by fire (Duncan and Dalton 1982; Longton 1992). Post-primary bryophyte succession of regenerating to mature boreal forest communities is well documented (Muhle and LeBlanc 1975; Heinselman 1981; Söderström 1988a; Crites and Dale 1998; Jonsson and Esseen 1998; Vellak and Paal 1999; Boudreault *et al.* 2000; Rambo 2001). In these ecosystems information on the vital attributes of bryophyte species is available (for example see Crum 2001). Vital attributes of rainforest and *Eucalyptus* species in wet eucalypt forests are largely known (Jackson 1999; Wells and Hickey 1999). Patterns of succession or replacement sequences based on recurrent fire disturbances have been derived for vascular plant species in Tasmanian mixed forest (Noble and Slatyer 1980). Little knowledge exists of bryophyte species vital attributes in post-primary successional stages of wet eucalypt forest communities. It is possible that similar successional pathways to those found for vascular plants in wet eucalypt forest may exist for bryophyte species that are associated with these vascular plant species (Crum 2001).

Thesis aims and structure

The main aim of this thesis is to determine the factors that affect bryophyte species richness and composition in wet eucalypt forest within different age classes since two types of disturbance. A survey of wet eucalypt forest of different ages in forests of Tasmania was made to record the presence/absence of bryophyte and vascular species. Associations between bryophytes and vascular species and bryophytes and site history

were studied regarding substrate variability, forest structure, lifeform and environmental factors.

In Chapter 2, the diversity of old growth mixed forest bryophytes, and relationships between bryophyte species richness, and composition, and the environment are investigated. This chapter addresses the following questions: (a) How variable is species richness and composition of bryophytes, liverworts and mosses between old growth sites? (b) Do species richness and composition of bryophytes, mosses and liverworts respond to the same environmental variables?

In Chapter 3 bryophyte species succession from early aged wet eucalypt forest through to old growth mixed forest is described. Two questions are the focus of the chapter (1) Are any bryophyte species found only in one age class? (2) Is there a temporal sequence in the appearance and disappearance of bryophyte species for (a) all sites? (b) *Eucalyptus regnans* dominated forest (c) *E. obliqua* dominated forest?

Chapter 4 describes relationships between the species richness of bryophyte and vascular plant lifeforms in old growth and regenerating wet eucalypt forest. The use of vascular plants as surrogates for bryophytes in wet eucalypt forest of different ages is investigated through minimum reserve sets and species composition. The following questions are addressed: (1) Are the species richness of mosses, liverworts and bryophytes as a group, significantly related to the species richness of trees, tall shrubs, short shrubs, non-woody angiosperms, all ferns, ground ferns, epiphytic ferns and all vascular plants? (2) To what degree can vascular species composition be used as a surrogate for bryophyte species composition? (3) Does predictability differ between old growth forest and earlier stages in succession after fire?

Chapter 5 presents the first study to investigate bryophyte species composition and distribution on substrates in different ages of wet eucalypt forest. Previous similar Australian studies (Ashton 1986; Jarman and Kantvilas 2001b; Pharo and Beattie 2002) have not included a temporal component. The possibilities of unique substrates/species to a single age class and the disappearance of species with a substrate or group of substrates are examined. Bryophyte species composition and distribution on substrates in different ages of wet eucalypt forest is investigated through the following questions: (1) are there substrates/species only found in one age class and do these unique

substrates have species not found in other age classes? (2) are there species that would disappear without a particular substrate or group of substrates? (3) in similar aged forest, is there a difference in species composition between substrates? (4) does the substrate preference of species change between different ages of forest?

The question of whether silvicultural practices imitate natural ecological processes such as fire, is examined in Chapter 6, with the primary focus on bryophytes although vascular plants are also included. Specifically, these hypotheses are investigated: (1) are the proportion of sites with each bryophyte and vascular species the same for each disturbance type? (2) does species composition of bryophytes and vascular plants differ between disturbance types and if so (3) what environmental variables explain the variation in species composition between forest types?

Finally, Chapter 7 will discuss the relative significance of bryophytes and their ecological role in wet eucalypt forest of different ages since disturbance. The possible impacts of forest management will be reviewed and recommendations for future research and management made.

Each chapter has been written in the format of a journal article, therefore some repetition has been unavoidable. The reader is referred to previous chapters for information where appropriate.

Chapter Two

Bryophyte relationships with environment in Tasmanian old growth wet eucalypt forest.

Abstract

The species richness and species composition of bryophytes (mosses and liverworts) was recorded at 33 sites in Tasmanian old growth wet eucalypt forest. A total of 202 bryophytes were recorded, consisting of 115 liverwort and 87 moss species. This constitutes approximately one third of the total bryophyte flora for Tasmania. Mean liverwort species richness per site was higher than moss species richness. Sites of more southerly latitudes had consistently greater mean richness for both liverwort and moss species. Three latitudinal bands had significantly different bryophytes species composition. Multiple regression models found latitude, mean annual temperature and rainfall of the driest month were positive significant predictors of bryophyte species richness. Moss species richness was significantly predicted by slope. Liverwort species richness was predicted by latitude, basal area of Eucalyptus *spp. and basal area of* Dicksonia antarctica. *Of the environmental variables, mean annual temperature, altitude, rainfall of the driest month and aspect were most significant in predicting variation in bryophyte species composition. Latitude was the strongest predictor for the models of bryophyte and moss species composition and the weakest predictor for liverwort species composition. The only other predictor in all models was the basal area of* Dicksonia antarctica. *It is likely that the strong relationship between bryophyte species composition and aspect and temperature in the present study is a consequence of protection from fire. A difference in bryophyte species composition between latitudinal bands suggests that, as well as significant environmental variables,* a priori *geographic boundaries distinguish bryophyte species composition in old growth mixed forest. To establish if there is a distinct biogeographical distribution for some bryophyte species in old growth mixed forest, further research is needed.*

Introduction

Studies on the relationships of bryophyte species richness and composition with environmental variables have largely focused on boreal forests of the northern hemisphere (La Roi and Stringer 1976; Slack 1977; Lee and La Roi 1979b; Økland and Eilertsen 1994; Wolf 1994; Rey Benayas 1995; Frisvoll and Presto 1997; Ohlson *et al.* 1997). In Australia, the only similar studies have been undertaken in eucalypt forest of the east coast of New South Wales and wet eucalypt forest of north eastern Tasmania (Pharo and Beattie 1997; Pharo *et al.* 1999; Pharo and Blanks 2000).

Many studies have included variables at a substrate or micro scale and/or a site or macro scale (Lee and La Roi 1979b; Økland and Eilertsen 1994; Rey Benayas 1995; Vitt *et al.* 1995; Frisvoll and Presto 1997; Pharo and Beattie 2002). Pharo and Beattie (2002), in modelling bryophyte species composition, demonstrated the value of including variables that were relevant to different substrates. Models included site variables more often than variables pertaining to a substrate, however these latter variables often appeared as the best predictor variable. Elsewhere, the number of uprooted trees was positively correlated with liverwort species richness, and moss species richness was positively correlated with number of deciduous trees (Frisvoll and Presto 1997). In Canadian boreal forests, substratum diversity was highest in forest communities and species richness was positively correlated with the number of substrates per stand (Lee and La Roi 1979b). Bryophyte species richness was positively correlated with number of substrate types per stand in wet eucalypt forest of northeast Tasmania (Pharo and Blanks 2000).

Many studies have found that altitude is an important environmental control on bryophyte species richness and composition. In the montane forest of British Columbia, bryophyte species richness was negatively correlated with altitude (Rey Benayas 1995). Ohlson (1997) found a similar relationship existed for bryophyte, moss and liverwort species richness in rare old growth swamp forests of northern Sweden. In contrast, bryophyte species richness is strongly positively correlated with altitude in boreal forest of the Canadian Rockies (Lee and La Roi 1979b). In non-forest vegetation, similar positive relationships between bryophyte species richness and altitude have been found (Gould and Walker 1999). For bryophyte species composition, altitude was a minor but

significant variable in describing bryophyte variation in lowland coastal forests of eastern Australia (Pharo and Beattie 1997) and an important variable in Canadian boreal forests (Lee and La Roi 1979a; Bradfield and Scagel 1984). Associated with altitude, temperature has also been found to be significantly negatively correlated with bryophyte species richness (Vitt *et al.* 1995). Aspect has been found to affect bryophyte species richness, with a greater number of liverwort species found on less exposed slopes (Söderström 1981).

Nutrients are thought to be more important for vascular plants than for bryophytes and as such, affect the composition of vascular plants more than bryophytes (Økland and Eilertsen 1994). Bryophytes respond to pH gradients, whereas vascular plants follow nutrient gradients (Vitt and Chee 1990). For example, bryophyte species richness was positively correlated with pH in the peatlands of North America (Glaser *et al.* 1990).

This study is the first to record the diversity of old growth wet eucalypt forest bryophytes, and to investigate relationships between bryophyte species richness, and composition, and the environment. In particular the following questions are addressed: (a) How variable is species richness and composition of bryophytes, liverworts and mosses between old growth sites? (b) Do species richness and composition of bryophytes, mosses and liverworts respond to the same environmental variables?

Materials and Methods

Study area

Data were collected from 33 sites (Figure 2.1), 27 of which were sampled earlier by Hickey and Savva (1992) in a vascular plant study. These original 27 sites were not permanently marked but were approximately relocated using grid references. Six of the original sites had been clearfell logged since 1992 and alternative sites were found using the methods of Hickey (1994). Selection of alternative sites was from Forestry Tasmania photo interpretation maps, from areas classified as current old growth mixed forest with a eucalypt height potential of 41 m. All sites were below 700 m. For the purpose of this study, this definition of old growth mixed forest will be used with the additional criteria that all old growth mixed forest is at least 110 years old without any signs of natural or man made disturbance (Commonwealth of Australia and the State of Tasmania 1996). Sites fall into three latitudinal bands. These latitudinal bands are

defined by, geographic separation, eucalypt dominance, vascular species composition and geology. Sites of northern Tasmania are dominated by *Eucalyptus obliqua* and *E. brookeriana*. The geology is principally siliceous including siltstone and mudstone, with some areas on the argillaceous rock, basalt. In the central forest *E. regnans* is dominant with occasional *E. obliqua* as a co-dominant. The geology of this area is predominantly siliceous rocks (mudstone and siltstone) with limestone also. The southern forests were dominated by *E. obliqua* with *E. delegatensis* or *E. regnans* sometimes co-dominating. The geology of the southern forests is mainly igneous (dolerite). Mean annual temperature ranges from 6.1 to 12.1 °C (average 9.95 ± 0.3 °C) and mean annual rainfall is from 1147 to 2104 mm (average 1502.21 ± 26.593 mm). Site characteristics are given in Table 2.1 and Appendices 8.1 and 8.2.

Table 2.1. Environmental variables for old growth mixed forest sites.

Variable	Mean ± SE	Range
Latitude (°east)	42.105471 ± 0.15	41.0388 – 43.24095
Altitude (m)	298.18 ± 31.37	40.00 – 633.00
Aspect (°)	180.62 ± 15.34	18.30 – 350.00
Mean annual temperature (°C)	9.95 ± 0.30	6.10 – 12.10
Mean annual rainfall (mm)	1502.21 ± 26.59	1147.00 – 2104.00
Rainfall driest month (mm)	70.18 ± 1.51	55.00 – 94.00
Slope (°)	9.29 ± 1.19	1.30 – 25.70
pH	5.11 ± 0.14	3.50 – 6.50
Total Nitrogen (% dry weight)	0.37 ± 0.04	0.15 – 1.07
Available Phosphorus (ppm)	14.6 ± 3.47	1.83 – 108.05
% Cover of above ground substrates	19.71 ± 0.92	11.29 – 30.19
% Canopy cover	83.44 ± 1.41	57.43 – 97.21
Number of substrate types per site	13.24 ± 0.61	7.00 – 20.00
Basal area of *Eucalyptus* spp. ($m^2 ha^{-1}$)	8.30 ± 0.89	0.67 – 22.67
Basal area of rainforest species ($m^2 ha^{-1}$)	24.63 ± 1.49	8.00 – 40.67
Basal area of *Dicksonia antarctica* ($m^2 ha^{-1}$)	13.32 ± 2.05	0.00 – 42.67
Basal area of dead trees ($m^2 ha^{-1}$)	0.81 ± 0.29	0.00 – 8.67

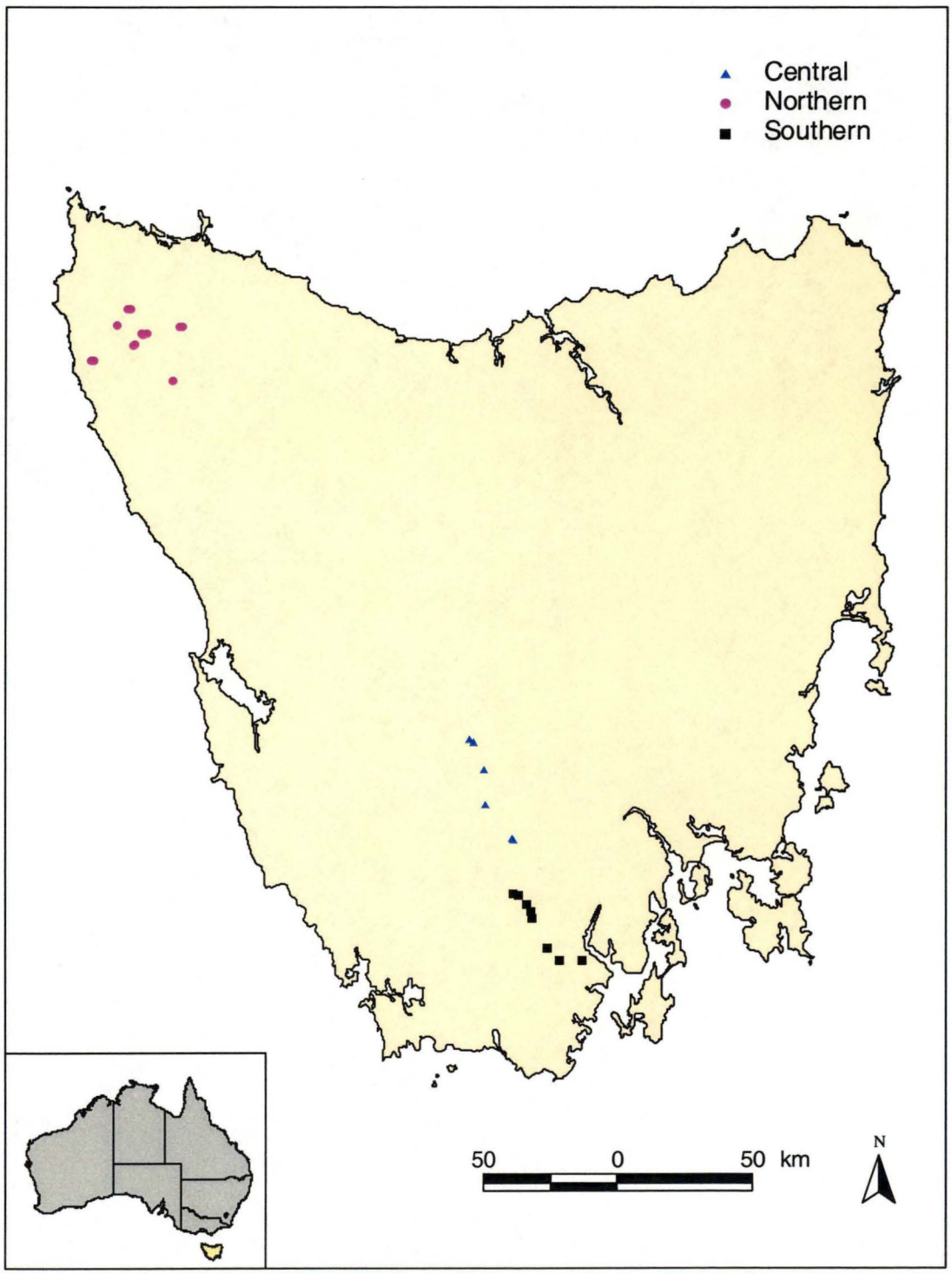


Figure 2.1. Location of old growth mixed forest sites in Tasmania.

Vegetation sampling

Fieldwork was undertaken from October 1999 to February 2000 and October 2000 to March 2001. A transect of 25 x 2 m was surveyed for bryophytes within homogenous old growth forest of southern Tasmania at Warra Long Term Ecological Research site (Brown *et al.* 2001) to determine an appropriate quadrat size. The species area curve tapered off at an area of 37.5 m^2 (Figure 2.2) with one additional area not adding new species. To ensure a greater chance of finding all species representative of the forest area, three transects each 25 x 2 m were surveyed at each site in homogenous forest. These were placed subjectively to cover the perceived heterogeneity of microhabitats, because although the forest proper may be homogenous, microhabitats may not. Furthermore, if a substrate was not found inside the sampling area, it was sought outside to a distance of 10 m (Pharo and Blanks 2000). At each site, the forest was sampled for the presence/absence of bryophytes and vascular plants using these three transects, 25 m x 2 m. All sampling was done from ground level. Epiphytic substrates were sampled along their length up to 2 m above ground level. This was considered to be a reasonable limit for ground-based surveying. Fallen branches were sampled to include canopy flora. If a substrate was not found within the sampling area, it was sought for within 10 m outside of the sampling area. Transects were located at a distance > 50 m from the road edge. Occasionally patches within sites were unsuitable because there was light selective logging or no burn scars from wildfire. A site was then sought by continuing further into the forest. Each transect was placed perpendicular to the slope. Presence/ absence data from the three transects per site were pooled to calculate site values. Nomenclature follows Dalton *et al.* (1991) for mosses, Ratkowsky (1987) for liverworts and Buchanan (1999) for vascular plants except where authorities are given.

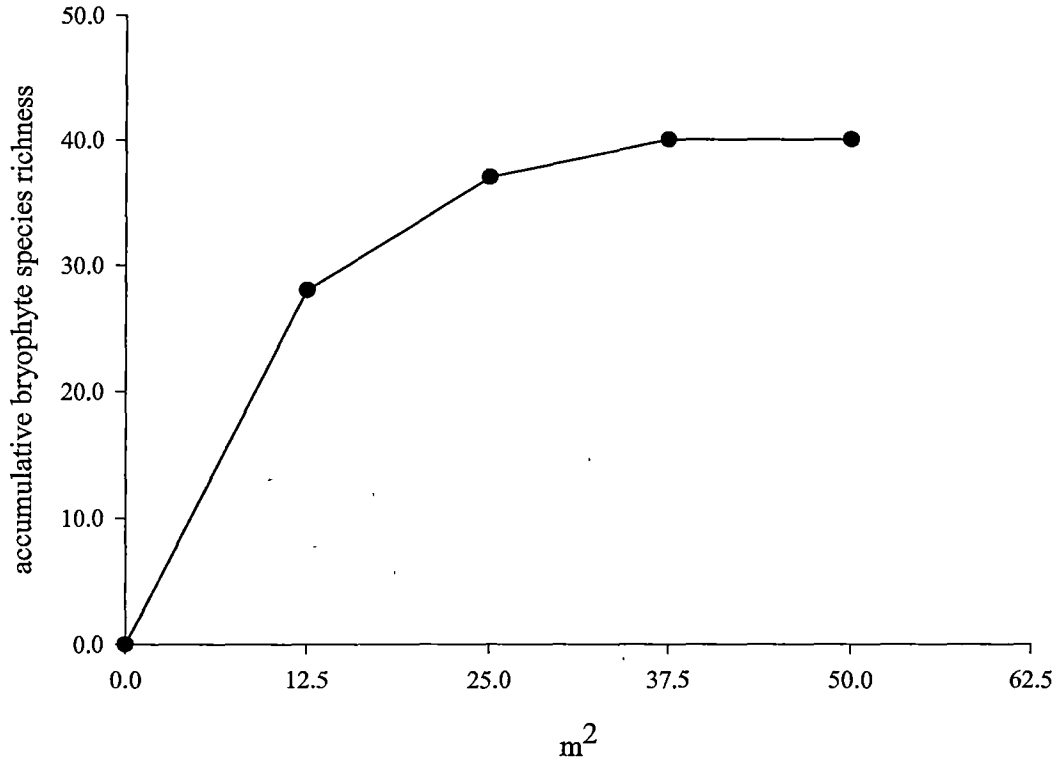


Figure 2.2. Species accumulative species richness curve for bryophytes in homogenous old growth mixed forest.

Environmental variables

Environmental measurements were recorded from each of the three transects. A single value for each site was used for latitude (°), geology, mean annual temperature (°C), mean annual rainfall (mm), rainfall of the driest month (mm), total nitrogen (%dry soil weight), available phosphorus (ppm) and the number of substrates per site. A mean value was used for remaining variables; aspect (°), slope (°), pH, altitude (m), % canopy cover, % cover of above ground substrates and basal area of: rainforest trees (as defined by Jarman *et al.* 1991) (see Appendix 8.3); *Eucalyptus* spp.; *Dicksonia antarctica,* and dead trees ($m^2 ha^{-1}$, Bitterlich wedge method, Mueller-Dombois and Ellenberg 1974). Details of variable ranges are given in Table 2.1.

Latitude and geology were recorded from relevant 1:25,000 maps. Geology was divided into three classes; 1 = carbonate, 2 = igneous, 3 = siliceous.

Mean annual temperature, mean annual rainfall and rainfall of the driest month were predicted by the BIOCLIM part of the ANUCLIM package (Centre for Resource and Environmental Studies 1999). BIOCLIM is a computer-based technique known collectively as the Bioclimatic Prediction System that generates predictions of climatic attributes from existing climatic data and interpolation based on distance and altitude. It produces a set of indices at any specified latitude, longitude and altitude that are considered to have biological significance and that summarise annual and seasonal mean conditions, extreme values and intra-year seasonality (Nix 1986). Mean annual temperature and mean annual rainfall is the mean of all the weekly mean temperatures and rainfall respectively. Each weekly mean temperature/rainfall is the mean of that week's maximum and minimum temperature.

After removing obvious litter and other plant material from the soil surface, samples of 5 x 5 x 5 cm^3 were taken at each end and the middle of transects. These samples were then bulked per site and air-dried. Once dry, soils were coarsely sieved to remove root, stones and litter material, and then soils were further sieved to pass through 0.5 mm. Soil was analysed for available phosphorus using the Bray fluoride extractable method and for total nitrogen using Kjeldahl method (Jackson 1958).

Aspect was recorded in degrees and later grouped into 5 classes (1 = northwest, 2 = north or west, 3 = northeast of southwest, 4 = east or south, 5 = southeast). Slope was measured in degrees from the horizontal using a clinometer from the centre of each transect.

pH was measured at each transect with a Manutec Soil pH test kit, which measures pH on a logarithmic scale ranging from zero to fourteen with intervals of 0.5. The three pH values for a site were converted to hydrogen ion concentration, and the mean calculated. The mean was reconverted and rounded to the nearest 0.5 for agreement with the original scale interval.

Canopy cover was calculated using a photo taken in the centre of each transect with immediate obscuring vegetation removed. Each photo was taken with the maximum focal length (30 mm – 80 mm) and at a constant height (1.7 m). At a threshold value for each negative, percentage canopy cover was recorded as the number of dark pixels within a centred circle on the negative.

Above ground substrates included vascular plant species, logs (greater than 10 cm diameter), fallen branches (less than 10 cm diameter), rocks, roots, dead trees, stumps, upturned root bases and *Dicksonia antarctica* (Treeferns). Treeferns were recorded in three states; alive (vertical stands only), fallen (horizontal and dead) or stumps (vertical and dead).

Analysis

A total of 76 vascular plant species were recorded from the 33 sites. The significance of variation in vascular species composition between latitudinal bands was tested using an Analysis of Similarities (ANOSIM, Clarke 1993), using DECODA (Minchin 1990, 1000 permutations). ANOSIM considers the differences in floristics between groups of samples and compares those differences with those found within groups. ANOSIM constructs a test statistic (R). This statistic is a valuable measure of the degree of separation of sites. The denominator is such that R can never lie outside the range –1 to 1. If R = 1 then all quadrats within groups are more similar to each other than any quadrats from different groups and if R = 0, then the null hypothesis is true, the dissimilarities between and within groups will be the same on average. It is possible for R to be significantly different from zero yet inconsequentially small, if there are many quadrats at each site (Clarke 1993). Values smaller than zero indicate greater dissimilarity among samples within groups than between groups. The significance of R was calculated by comparing the test statistic to 1000 random permutations. The significance levels of pairwise tests are not adjusted by ANOSIM to consider multiple comparisons. Values of 'p' falling close to 0.05 should be interpreted with care (Clarke 1993).

Species richness

Bryophyte species presence-absence was entered into the data package DECODA (Minchin 1990). Species richness was calculated as the number of species at a site. Analysis of variance was used to determine differences in species richness for bryophyte, moss and liverworts between northern, central and southern Tasmania. Tukeys test was used to denote different means at the 95% confidence interval. Simple and multiple regression was used to investigate relationships between species richness of moss, liverwort and all bryophytes and the environmental variables. Three variables with skewed distribution, % canopy cover, basal area of *Eucalyptus* spp. and basal area

of rainforest species, were log transformed to satisfy normality requirements. Colinearity of variables was checked using Pearson's product moment correlation co-efficient (Sokal and Rohlf 1995).

Species composition

The indirect ordination method, non-metric multidimensional scaling (NMDS) was used to produce ordinations of bryophyte, moss and liverwort species composition for 33 old growth sites (DECODA, Minchin 1990) using the recommended Bray-Curtis dissimilarity co-efficient (Faith *et al.* 1987). The NMDS ordinations were performed in 1 to 4 dimensions using 10 different random initial configurations. A plot of stress versus the number of dimensions was used to select the dimension that adequately reflected the differences in species compositions among samples. Three-dimensional ordinations were selected. The significance of variation in bryophyte, moss and liverwort species composition between latitudinal bands was then tested using an Analysis of Similarities (ANOSIM, Clarke 1993), using DECODA (Minchin 1990, 1000 permutations).

Relationships between bryophyte, moss and liverwort species composition and non-transformed environmental variables were explored initially using vector fitting (Kantvilas and Minchin 1989). The technique maximises the linear correlation of a given variable within the ordination. The length of the line from the zero origin to the co-ordinates for the variable depicts the strength of the relationship with species composition. The significance of the relationship was tested using permutation (1000 permutations). Trends in species composition along the vector with the highest correlation for each ordination are summarised by initially excluding species occurring in less than 5 sites and then calculating the percentage frequency of remaining species within 10 contiguous segments along the vector. Condensed ordered tables were produced. The order of species is defined by their weighted average along the vector using DECODA (Minchin 1990).

Environmental variables were further related to variation in bryophyte, moss and liverwort species composition using the direct ordination method, Redundancy Analysis (RDA) also known as reduced rank regression (ter Braak and Prentice 1988). RDA was used because species responses to environmental variables were presumed to be monotonic (not linear). NMDS assumes a monotonic relationship between ordination

distance and compositional dissimilarity. RDA finds the environmental variables that explain most of the variance in the species scores on each axis by applying multiple regression. The analysis was performed using CANOCO 4.0 (ter Braak 1991). NMDS ordination scores for each three dimensional axis were entered as dependant variables (species data) with environmental variables entered as the independent variables. Forward selection of variables was used where, once the variable explaining the most variance was added first to the model, the fit and significance of remaining variables were assessed and significant variables added in turn. Significance of the environmental variables was tested using 1000 random permutations with $\alpha = 0.05$. Eigenvalues show the variance in species scores explained by the environmental variables (scaling 1 in CANOCO 4.0). The percentage variance in species data explained by each variable was calculated by dividing the variance in species data accounted for by each variable by the total variance (ter Braak 1991).

Results

ANOSIM found significant differences in vascular species composition among latitudinal bands ($R = 0.44$, $p < 0.000$) and between latitudinal bands (Northern - Southern, $R = 0.48$; Northern - Central, $R = 0.43$; Southern - Central, $R = 0.43$; all pairwise tests $p < 0.000$).

Species richness

A total of 202 bryophyte taxa were recorded from the 33 old growth sites. This included 87 moss and 115 liverwort species. Six species occurred at all sites: *Bazzania involuta, Lepidozia ulothrix, Teleranea patentissima, Dicranoloma menziesii, Ptychomnion aciculare* and *Rhapidorhynchium amoenum.* Seventeen mosses and fourteen liverworts were recorded only once. The range of species richness for bryophytes was 50 - 110, with the range for moss and liverwort species being 18 – 46 and 24 – 64 respectively. Mean species richness for bryophytes was 66.12 ± SE 2.15 with mean species richness of mosses being lower than that for liverworts (27.91 ± SE 0.92 and 38.21 ± SE 1.76 respectively).

Mean species richness of bryophytes was similar in central and northern latitudes but was greater in the southern latitudes (Table 2.2). The higher value in the south is due to

liverworts, which contributed most to total bryophyte species richness. Moss species richness did not differ significantly between latitudinal bands.

Table 2.2. Summary of bryophyte, moss and liverwort species richness and species totals in each latitudinal band. ANOVA was used to compare the mean species richness. Tukeys test was used to denote different means at the 95% confidence interval, indicated by differing superscripts. p value > 0.05 is not significant (ns). Total number of bryophytes = 202 species (87 moss and 115 liverwort species).

	Latitudinal band	Total number of species	Mean species richness	Standard error	Minimum species richness	Maximum species richness	p value
Bryophyte	Central	138	61.00^{A}	2.60	50	77	0.000
	Northern	150	60.87^{A}	1.31	53	72	
	Southern	166	82.38^{B}	4.50	73	110	
Moss	Central	65	28.80^{A}	1.33	23	38	ns
	Northern	59	25.87^{A}	0.77	18	29	
	Southern	66	30.63^{A}	2.92	19	46	
Liverwort	Central	73	32.20^{A}	1.97	24	42	0.000
	Northern	91	35.00^{A}	1.61	28	50	
	Southern	100	51.75^{B}	2.70	41	64	

Three variables were significantly positively correlated with bryophyte species richness: latitude, slope and percentage cover of above ground substrates (Table 2.3). These three variables were also significantly positively correlated with moss species richness. Liverwort species richness was positively correlated with latitude, number of substrate types per site, and negatively correlated with basal area of *Dicksonia antarctica*. In the multiple regression models, latitude, mean annual temperature and rainfall of the driest month were all positively related to bryophyte species richness (y = -799.00 + 17.10 X latitude + 8.75 X mean annual temperature + 0.85 X rainfall of the driest month; r^2 = 0.53, d.f. = 32, F = 10.69, p = 0.000). Only slope was positively related to moss species richness (Table 2.3). Liverwort species richness was positively related to latitude, and negatively related to basal area of *Eucalyptus* spp. and basal area of *Dicksonia antarctica* (y = - 133.00 + 4.23 X latitude –1.32 X basal area of *Dicksonia antarctica* – 10.60 X basal area of *Eucalyptus* spp.; r^2 = 0.46, d.f. = 32, F = 8.34, p = 0.000). Soil variables (pH, available phosphorus and total nitrogen) did not contribute in the explanation of variation in species richness of bryophytes, mosses or liverworts.

*Table 2.3. Variance explained (r^2) by environmental variables for bryophyte, moss and liverwort species richness. Positive or negative signs indicate the relationship. *p < 0.05, **p < 0.01, ***p < 0.001, ns = not significant.*

	All bryophytes	Mosses	Liverworts
Latitude (°east)	+ 0.28**	+ 0.15*	+ 0.19*
Altitude (m)	ns	ns	ns
Aspect (°)	ns	ns	ns
Mean annual temperature (°C)	ns	ns	ns
Mean annual rainfall (mm)	ns	ns	ns
Rainfall driest month (mm)	ns	ns	ns
Slope v	+ 0.16*	+ 0.19*	ns
pH	ns	ns	ns
Total Nitrogen (%dry soil weight)	ns	ns	ns
Available Phosphorus (ppm)	ns	ns	ns
% Cover of above ground substrates	+ 0.16*	+ 0.14*	ns
% Canopy cover	ns	ns	ns
Number of substrate types per site	ns	ns	+ 0.15
Basal area of *Eucalyptus* spp. (m^2 ha^{-1})	ns	ns	ns
Basal area of rainforest species (m^2 ha^{-1})	ns	ns	ns
Basal area of *Dicksonia antarctica* (m^2 ha^{-1})	ns	ns	- 0.21
Basal area of dead trees (m^2 ha^{-1})	ns	ns	ns
Geology	ns	ns	ns

Species composition

The three-dimensional ordinations for bryophyte, moss and liverwort species composition, with the vectors fitted for environmental variables with significant correlation are shown in Figure 2.3. The ordinations suggest there is differentiation of bryophyte species composition by latitudinal band. ANOSIM found significant differences in species composition among latitudinal bands (bryophyte, R = 0.58; moss, R = 0.55; liverwort, R = 0.45; all pairwise tests $p < 0.000$). The vectors with significant correlations within the ordinations were altitude, latitude, rainfall of the driest month, mean annual temperature, aspect, slope, basal area of *Dicksonia antarctica*, % cover of above ground substrates and number of substrate type per site (Table 2.4). There is a strong separation of sites from northern to southern latitudes. For bryophyte, moss and liverwort species composition, the vectors for latitude, altitude and rainfall of the driest month are negatively related to mean annual temperature. This latter variable is high in sites of more northerly latitude. The vectors for the variables, slope and % above ground cover of substrates are only significantly related to moss species composition. The vector representing number of substrate types per site is related to moss species composition of southern and central sites. The basal area of *Dicksonia antarctica* is a significant variable for bryophyte species composition. These results suggest bryophyte species composition in sites of northerly latitudes are associated with warmer

temperatures. In addition, at cooler latitudes, slopes influence moss species composition and number of substrates types available for colonisation.

Bryophyte species composition along the vector of mean annual temperature is presented in Table 2.5. Species range from lower temperatures (for example, *Chandonanthus squarrosus* and *Distichophyllum* species) through to medium temperature (*Radula tasmanica, Teleranea centipes* and *Brevianthus flavus*) to higher temperature species (*Macromitrium microstomum, Fissidens taylorii* and *Papillaria flavo-limbata*).

RDA analyses and the vector fitting procedure produced similar results. Latitude, altitude, aspect, mean annual temperature, rainfall of the driest month, and basal area of *Dicksonia antarctica* were significant in explaining bryophyte and liverwort species composition (Table 2.6). The number of substrates per site was also significant for bryophyte and moss species composition. Slope and % cover of above ground substrates were also significantly correlated with variation in moss species composition.

Latitude was the strongest predictor for the models of bryophyte and moss species composition. It was the weakest predictor for liverwort species composition. The only other predictor in all models was the basal area of *Dicksonia antarctica*. pH was included for the models of bryophyte and liverwort species composition. Eigenvalues were similar for bryophyte, moss and liverwort species composition (bryophyte: axis 1 = 0.372, axis 2 = 0.284, axis 3 = 0.193; moss: axis 1 = 0.404, axis 2 = 0.254, axis 3 = 0.199, liverwort: axis 1 = 0.341, axis 2 = 0.293, axis 3 = 0.120).

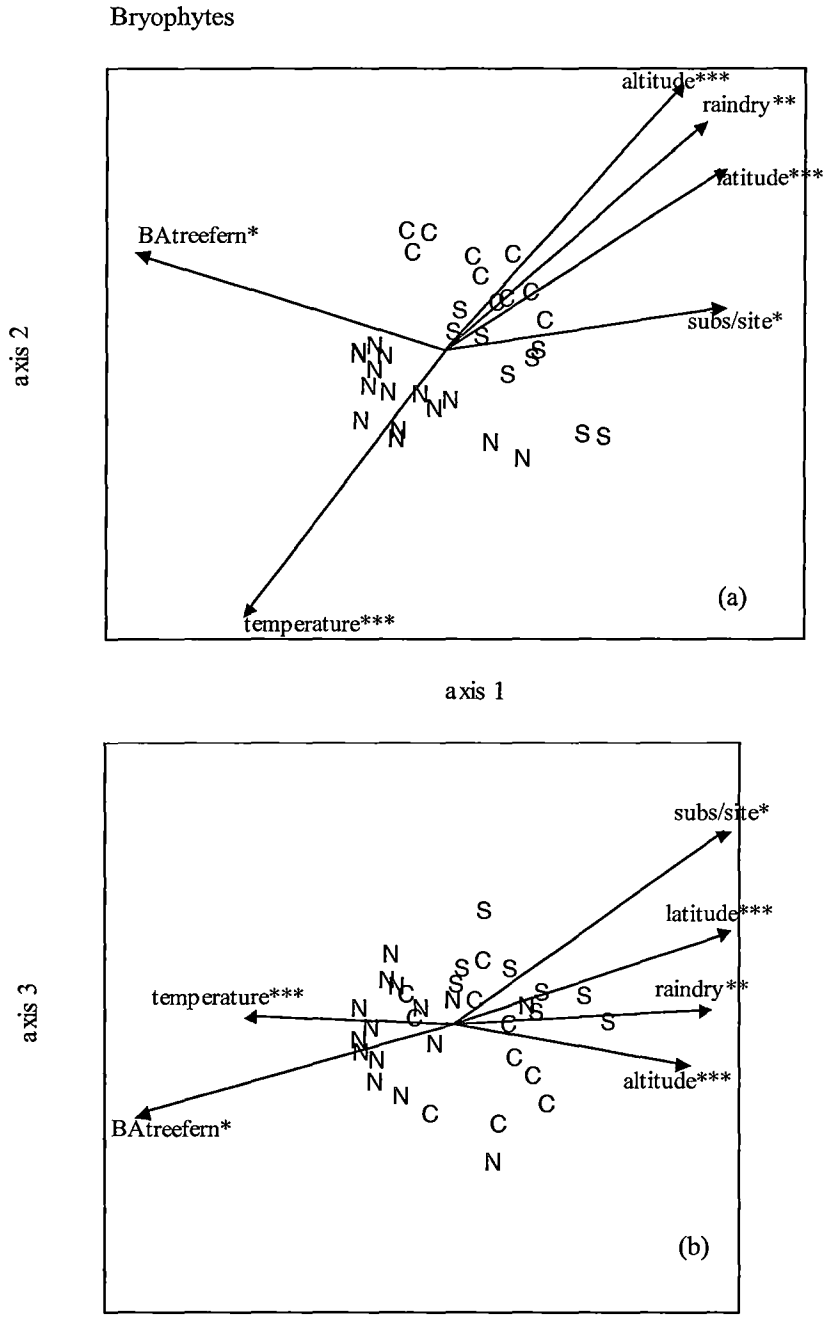
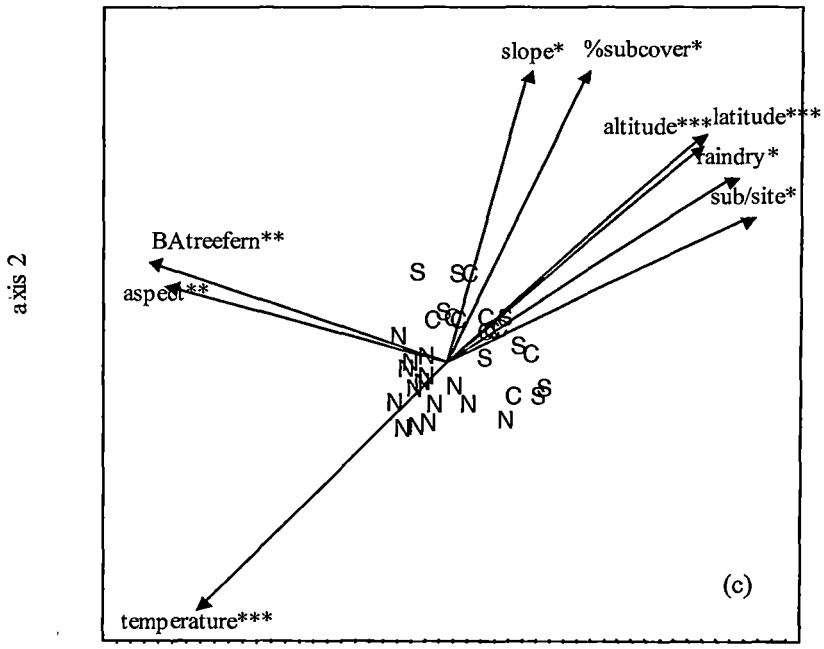
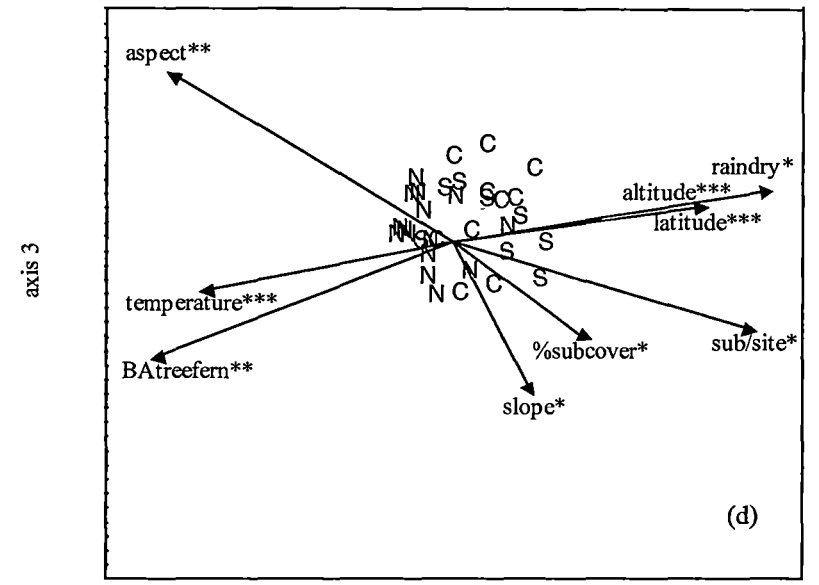


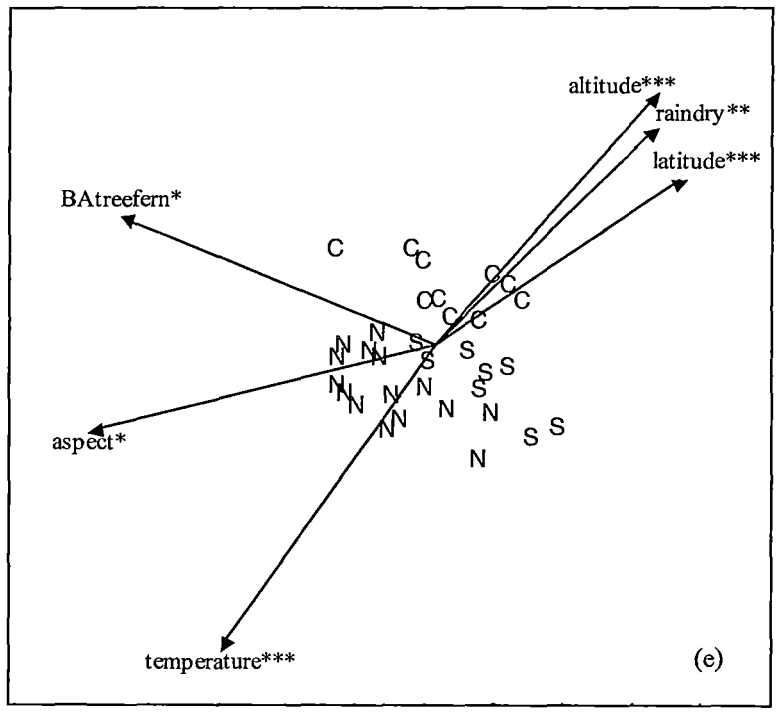
Figure 2.3. Three-dimensional bryophyte, moss and liverwort ordinations of sites in old growth mixed forest, (a - b) bryophytes stress = 0.1547, (c - d) mosses stress = 0.177, (e – f), liverworts stress = 0.146. Latitudinal bands: N = Northern, C = Central, S = Southern. Vectors with significant correlation with the ordination are shown: aspect, latitude, mean annual temperature (temperature), rainfall of the driest month (raindry), altitude, number of substrate types per site (subs/site), slope, % cover of above ground substrates (% subcover) and basal area of Dicksonia antarctica *(BAtreefern). * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.*

Mosses


slope* %subcover*
altitude*** latitude***
raindry*
sub/site*
BAtreefern**
aspect**
temperature***
(c)
axis 2
axis 1


aspect**
raindry*
altitude***
latitude***
temperature***
%subcover*
sub/site*
BAtreefern**
slope*
(d)
axis 3
axis 1

Liverworts


altitude***
raindry**
latitude***
BAtreefern*
aspect*
temperature***
(e)
axis 2
axis 1

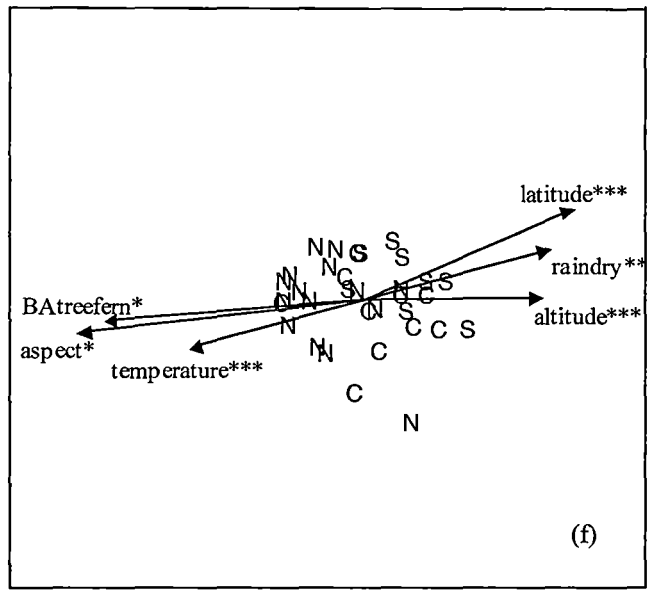

latitude***
raindry**
BAtreefern*
altitude***
aspect*
temperature***
(f)
axis 3
axis 1

*Table 2.4. Vector results for ordination of old growth mixed forest. R value for environmental vectors. * $p < 0.05$, ** $p < 0.01$, *** $p < 0\ 001$, ns = not significant.*

	Bryophytes	Mosses	Liverworts
Latitude v	0.92***	0.88 ns	0.84***
Altitude (m)	0.87***	0.75***	0.83***
Aspect (°)	0.49*	0.57*	0.52*
Mean annual temperature (°C)	0.92***	0.80***	0.88***
Mean annual rainfall (mm)	0.26 ns	0.29 ns	0.24 ns
Rainfall driest month (mm)	0.61**	0.56*	0.58**
Slope (°)	0.47 ns	0.52*	0.33 ns
pH	0.43 ns	0.33 ns	0.35 ns
Total Nitrogen (%dry soil weight)	0.27 ns	0.32 ns	0.21 ns
Available Phosphorus (ppm)	0.30 ns	0.38 ns	0.17 ns
% Cover of above ground substrates	0.37 ns	0.49 ns	0.30 ns
% Canopy cover	0.25 ns	0.38 ns	0.36 ns
Nº of substrate types per site	0.56*	0.54*	0.49 ns
Basal area of *Eucalyptus* spp. (m^2 ha^{-1})	0.44 ns	0.38 ns	0.32 ns
Basal area of rainforest species [a] (m^2 ha^{-1})	0.46 ns	0.39 ns	0.48 ns
Basal area of *Dicksonia antarctica* (m^2 ha^{-1})	0.54*	0.58**	0.50*
Basal area of dead trees (m^2 ha^{-1})	0.42 ns	0.28 ns	0.43 ns
Carbonate	0.33 ns	0.39 ns	0.30 ns
Igneous	0.42 ns	0.23 ns	0.38 ns
Siliceous	0.39 ns	0.16 ns	0.38 ns

[a] rainforest species as defined in (Jarman *et al.* 1991), (see Appendix 8.3).

Table 2.5. Occurrence of bryophyte species in old growth mixed forest along the fitted vector for Mean annual temperature. Dashes indicate sites from which species were absent. Species occurring in less than 5 sites are not shown. Latitudinal band: C = Central, S = Southern, N = Northern.

	C 85	C 90	C 80	C 91	C 73	C 65	C 79	C 64	C 69	C 70	S 39	S 40	S 34	S 1	S 36	S 30	S 4	S 32	N 29	N 8	N 22	N 23	N 19	N 21	N 49	N 24	N 51	N 25	N 18	N 28	N 50	N 48	N 5
Chandonanthus squarrosus	1	1	1	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Distichophyllum microcarpum	1	-	-	-	1	1	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thuidium sparsum	1	1	-	1	1	1	-	-	1	1	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plagiochila retrospectans	-	1	-	-	1	-	-	-	-	-	1	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Distichophyllum crispulum	1	1	-	-	-	1	1	-	-	-	-	1	1	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Catagonium nitens (Brid) Cardot ssp *nitens*	-	1	-	-	1	-	-	-	1	1	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kurzia hippuroides	1	1	1	1	-	1	1	-	-	-	1	1	1	1	1	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Distichophyllum pulchellum	1	-	-	-	1	1	1	1	1	-	1	1	1	1	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Metzgeria saccata	-	-	1	-	1	-	1	-	-	-	-	1	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tylimanthus pseudosaccatus	1	1	1	-	1	1	1	1	1	1	1	-	1	-	1	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-
Saccogynidium decurvum	1	-	1	-	1	1	1	1	-	-	1	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Thuidium furfurosum	-	-	-	-	1	-	-	-	1	-	-	-	1	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acrochila biserialis	1	1	1	-	1	1	1	-	-	1	1	1	-	1	-	1	1	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-
Glyphothecium sciuroides	1	1	1	1	1	1	1	-	1	-	1	1	1	-	-	1	1	1	-	-	-	-	-	-	1	-	1	-	-	-	1	-	-
Frullania rostrata	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	-	-	-	1	-	-	1	-	-	-	1	-	-	-	1
Lepicolea scolopendra	1	1	1	1	1	1	1	-	-	-	1	1	1	1	1	1	1	-	1	1	1	1	-	-	-	-	-	1	-	-	-	-	-
Weymouthia cochlearifolia	1	1	1	-	1	1	-	1	-	-	-	1	1	-	-	1	1	1	1	-	1	1	-	-	-	-	1	-	-	-	-	-	-
Dicranoloma robustum	1	-	1	1	-	1	1	1	1	-	1	1	-	1	-	1	1	-	-	1	-	-	-	-	1	-	1	-	1	-	-	-	-
Plagiochila radiculosa	-	1	-	-	1	-	-	-	-	-	1	1	-	-	1	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-
Hypnodendron spinnervium ssp *archeri*	-	1	1	1	1	1	1	1	1	1	1	-	1	1	-	-	1	1	-	1	1	-	-	1	-	-	-	1	1	-	-	-	-
Zygodon intermedius	-	1	1	-	1	-	1	1	-	-	1	1	1	-	1	-	-	-	1	1	-	-	-	1	-	-	1	-	-	-	-	-	-
Hypnodendron comosum	-	1	-	-	-	1	-	-	-	1	1	1	-	1	1	1	1	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-
Plagiochila circinalis	-	-	1	-	-	-	1	-	-	-	1	-	-	1	-	1	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Frullania falciloba	1	1	1	-	1	1	-	-	-	1	-	1	1	1	1	-	-	-	1	-	-	1	1	-	-	-	-	1	1	-	-	-	-
Dicranoloma robustum var *setosum*	1	1	-	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	-	-	-	1	-	-	-	1	-	1	-	1	-	1	-
Thamnobryum pumilum	1	1	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	1	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-
Telaranea centipes	-	-	-	-	-	-	-	1	-	-	-	1	1	1	1	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Radula compacta	-	-	1	1	1	1	1	1	-	-	1	1	-	1	1	1	1	1	-	1	1	-	-	1	1	-	-	-	1	-	-	-	-	-
Leptostomum inclinans	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	1	-	1	-	1	-	1	1	-	-	1	-	1	1	1	-	-
Camptochaete arbuscula	1	1	1	1	1	1	1	1	1	-	-	-	-	-	-	-	-	1	1	-	1	1	1	1	1	1	-	1	-	-	-	-	-	-
Balantiopsis diplophylla	-	1	1	-	1	1	1	1	1	1	1	1	1	-	1	-	1	1	-	-	1	-	1	1	-	-	-	1	1	-	-	1	-
Kurzia compacta	-	-	-	-	-	-	-	1	-	-	1	-	1	1	1	1	1	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Riccardia cochleata	1	-	-	-	-	1	-	-	-	-	1	-	-	1	1	1	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Gackstroemia weimdorferi	1	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	-	1	1	1	-	1	-	-	1	-	-
Tylimanthus tenellus	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	-	-	1	1	1	-	-
Radula tasmanica	-	-	-	-	-	-	-	1	-	-	1	-	1	1	-	1	1	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Zoopsis setulosa	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	1	1	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptophyllopsis laxus	-	-	-	-	-	-	-	-	-	-	1	-	1	1	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Zoopsis leitgebiana	1	-	-	-	-	1	-	1	-	1	1	1	1	-	1	-	1	1	-	1	-	-	-	-	-	-	1	1	-	-	-	-	1
Frullania aterrima	-	-	-	-	-	-	-	-	-	-	1	-	-	1	1	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopterygium limatum	-	-	-	-	1	-	-	-	-	-	-	1	-	1	1	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Plagiochila strombifolia	1	1	1	1	1	1	1	-	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1	1	1	1	-	-	-	1	1	-
Riccardia crassa	-	-	-	-	-	1	-	1	1	1	-	-	-	1	1	1	1	-	-	-	-	-	-	-	-	1	1	-	1	-	-	-	-
Acromastigum colensoanum	1	-	1	1	-	1	-	1	-	1	1	1	-	1	1	1	1	1	-	1	1	-	1	1	1	-	-	-	1	-	-	1	-
Frullania clavata	1	1	-	1	1	-	-	1	1	-	-	1	1	1	1	1	-	-	1	-	1	1	1	-	1	1	-	1	1	-	-	-	-
Brevianthus flavus	-	-	-	-	-	-	-	-	-	-	1	1	-	1	-	1	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chloscyphus leucophyllus	-	1	-	-	-	1	-	-	-	-	1	-	-	1	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	1	-	-
Symphyogyna podophylla	1	-	-	-	1	1	1	1	1	1	1	1	1	-	1	-	1	-	-	-	1	-	1	1	-	1	-	1	1	1	1	-	-
Lopidium concinnum	-	-	-	1	1	1	1	1	1	1	-	1	1	-	-	-	1	1	-	-	-	1	1	1	1	-	1	-	-	1	-	1	-
Lembophyllum divulsum	1	-	-	1	1	-	-	-	-	1	-	1	1	-	1	-	-	1	-	-	1	1	1	-	-	1	1	-	-	1	-	-	-
Metzgeria decipiens	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	1	1	1	1	1	1	1	1	1	1	-	1	1
Plagiochila fasciculata	1	1	-	1	1	1	1	1	-	-	1	1	1	1	1	-	1	-	1	-	1	1	1	-	-	1	1	1	-	1	1	-	1
Rosulabryum billardieri var *billardieri* (Schwägr) Spence	-	-	-	1	1	1	1	-	1	1	-	-	-	1	1	1	-	-	-	-	1	-	1	-	-	1	-	1	1	-	-	1	-
Tylimanthus diversifolius Hodgs	-	1	1	1	1	1	-	1	1	1	1	1	1	-	1	1	1	1	-	1	-	1	1	1	1	1	1	-	1	-	-	1	1
Weymouthia mollis	1	-	-	-	-	-	1	1	-	1	1	1	1	-	1	-	-	1	-	-	1	1	-	1	1	1	-	1	-	1	-	-	-
Hypnum cupressiforme	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	-	1
Heteroscyphus limosus	-	1	1	-	-	-	-	-	1	-	-	-	-	1	1	1	1	-	1	1	-	1	1	-	-	-	-	-	-	-	-	-	-	1
Rhapidorrhynchium amoenum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1
Rhizogonium novae-hollandiae	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1
Zoopsis argentea	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Warburgiella leucocytus (Mull Hal) Tan, Schofield & Ramsay	1	1	1	1	1	1	1	-	1	-	1	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	-	1	1
Heteroscyphus simosus	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-
Bazzania involuta	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dicranoloma menziesii	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lepidozia ulothrix	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ptychomnion aciculare	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Telaranea patentissima	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Wijkia extenuata	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mittenia plumula	-	-	-	-	1	-	-	1	-	-	1	1	-	-	1	-	1	-	-	-	1	-	1	-	-	-	-	-	1	-	-	1	-
Radula buccinifera	-	1	-	1	1	1	-	1	1	1	-	1	1	-	1	1	1	1	-	-	1	1	1	1	1	-	1	1	-	1	1	1	-

	C 85	C 90	C 80	C 91	C 73	C 65	C 79	C 64	C 69	C 70	S 39	S 40	S 34	S 1	S 36	S 30	S 4	S 32	N 29	N 8	N 22	N 23	N 19	N 21	N 49	N 24	N 51	N 25	N 18	N 28	N 50	N 48	N 5
Podomitrium phyllanthus	1	-	-	-	1	1	1	-	-	-	1	-	1	-	1	-	1	1	-	1	1	1	1	-	1	-	1	-	-	-	1	1	-
Leptotheca gaudichaudii	1	1	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Trichocolea mollissima	1	1	1	1	-	1	1	1	-	-	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	1	-	1	1
Hypnum chrysogaster	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fissidens pallidus	1	1	1	-	-	1	-	1	1	1	1	-	-	-	1	-	1	1	1	-	1	1	1	1	-	1	1	1	-	1	1	-	1
Schistochila lehmanniana	1	1	-	-	1	1	1	1	1	1	1	1	1	-	1	-	1	1	-	1	1	-	1	1	1	1	1	1	1	1	1	1	1
Bazzania monilinervis	1	1	1	-	-	1	1	1	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	-	1	1	1	1
Lepidozia procera	1	1	1	-	1	1	1	1	-	-	1	1	-	1	1	1	1	1	-	1	1	1	-	1	1	1	1	1	1	1	1	1	1
Dicranoloma dicarpum	1	-	-	1	1	1	-	-	1	1	1	-	-	-	1	-	1	-	1	-	-	-	-	-	1	1	1	1	1	1	1	-
Kurzia hippuroides aff.	1	-	-	-	1	-	1	1	-	-	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	-	1	-	-	1
Dicranoloma billardieri	-	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Macromitrium archeri	-	-	-	-	1	-	-	-	-	-	-	1	1	1	1	1	-	1	1	-	1	-	1	-	-	-	-	-	1	-	1	-	-
Marsupidium surculosum	-	-	1	-	-	1	-	-	1	1	1	1	1	1	-	1	1	1	-	1	1	-	-	-	1	-	-	1	1	-	1	1	1
Chiloscyphus echinellus	1	1	1	-	1	1	1	1	-	-	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fissidens tenellus	-	-	-	1	1	-	1	-	-	1	-	1	-	-	1	-	-	-	1	-	1	-	1	-	1	1	1	1	1	-	-	-	-
Heteroscyphus fissistipus	-	1	-	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Teleranea herzogii (Hodgs.) Hodgs	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	1	1	-	1	-	1	-	1	-	-	-	-	-
Hypnodendron vitiense ssp *australe*	-	1	-	-	-	-	-	-	1	-	-	-	1	-	-	-	1	1	-	-	1	-	-	1	-	-	-	-	-	1	1	-
Plagiochila baileyana	-	-	-	-	-	-	-	1	-	1	1	-	1	-	1	1	1	1	-	1	1	-	-	-	1	1	-	-	-	1	-	1	-
Cyathophorum bulbosum	1	-	-	-	1	1	1	1	1	1	-	-	1	-	1	-	1	1	1	1	1	1	1	1	1	-	1	1	-	1	1	1	1
Hymenophyton flabellatum	-	-	1	-	1	1	1	1	1	-	1	-	1	-	1	-	1	1	-	-	1	-	1	1	-	1	1	1	1	1	1	1	1
Campylopus introflexus	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1	-	1	-	1	-	-	-	1	-	-	1	-	-	1	-	-	-	-
Riccardia spp	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-
Lepidozia laevifolia	-	1	1	-	1	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	1
Orthodontium lineare	-	-	-	1	-	-	1	-	-	1	-	1	-	-	1	-	-	1	1	-	-	-	-	-	-	-	1	1	-	-	1	1	-	1
Achrophyllum dentatum	1	-	-	-	1	1	-	1	1	1	1	-	1	-	1	-	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Acrobolbus cinerascens	-	-	-	-	-	1	-	-	-	-	-	1	-	1	-	1	1	-	1	1	-	-	-	-	-	1	-	-	-	-	1	-	1	-
Riccardia aequicellularis	-	-	-	-	-	1	1	1	-	1	-	-	1	-	-	-	1	1	-	-	1	1	-	1	1	1	1	-	1	1	-	-	1
Heteroscyphus coalitus	-	1	-	1	1	-	-	-	1	1	1	1	1	-	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Heteroscyphus billardieri	-	-	-	-	-	-	-	-	-	-	1	1	-	1	-	1	-	-	1	1	1	-	-	1	-	-	-	-	-	-	-	-	1
Lepidozia glaucophylla	-	-	-	-	1	-	-	-	-	-	1	-	1	1	1	1	1	1	-	-	-	-	1	1	1	-	1	-	-	1	-	1	1
Paraschistochila tuloides	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	1	1	-	1	1	1	-	-	1	1	-	-	-	-	-	-	1	-
Leucobryum candidum	-	1	1	1	-	-	1	-	-	1	-	1	-	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cuspidatula monodon	-	1	1	-	-	1	1	-	-	-	1	1	-	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Heteroscyphus conjugatus	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	1	1	-	-	1	-	-	-	-	-	-	-	-	-
Chiloscyphus semiteres	-	1	-	1	1	-	-	-	1	-	-	-	1	-	1	-	-	-	-	1	-	1	1	1	1	-	1	1	1	1	-	1	1
Plagiothecium lamprostachys (Hampe) Jaeg	-	-	-	1	1	-	1	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	1	-	1	1	-	1	1	1
Dicranoloma platycaulon	-	-	-	-	-	-	-	-	-	-	1	-	-	1	1	-	1	-	-	-	-	1	-	-	-	1	1	-	1	-	1	-	-
Lejeunea drummondii	-	-	-	-	1	-	-	-	-	-	-	1	1	-	-	1	1	1	-	1	-	-	1	-	1	1	-	-	1	1	1	1	-
Lejeunea primordialis	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	1	-	-	-	-	-	1	-	1	-	-	-
Rhizogonium distichum	1	-	1	-	-	-	1	-	-	-	-	-	1	-	1	-	1	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1
Temnoma townrowii	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	1	-	1	-	-	-	-	-
Goniobryum subbasilare	1	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	1	1	-	-	1	-	1	-	-	-	1	1	1
Plagiochila spp	-	-	-	-	-	-	-	-	-	-	1	1	1	1	1	1	1	1	-	1	1	1	-	1	-	1	1	1	1	1	1	1	1
Telaranea mooreana	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	1	1	-	-	1	-	-	-	-	-	-	1	-	-
Adelanthus bisetulus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	1	-	1	-	-	-	1	-	-	-	-	-	1	-	-
Jamesoniella tasmanica	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	1	-	-	1	-	-	-	-	-	1	1	-	-	-	-
Pallaviciniaceae	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	1	-	-	1	-	-	1
Chiloscyphus muricatus	-	-	-	-	-	-	-	1	-	-	-	-	1	-	1	-	-	1	-	-	1	1	1	1	1	1	-	1	1	1	-	1	1
Macromitrium microstomum	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	1	1	-	-	-	-	1	-	1	-	-	1	-	-	1
Telaranea tetradactyla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1	-	-	1	1	1	-	-	-	-	1
Fissidens taylorii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	1	1	1	-	-	-
Papillaria flavolimbata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1	-	1	1	1	-	1	1	1	1	1	1

Table 2.6. Redundancy analysis results for bryophyte, moss and liverwort species composition explained by environmental variables. RDA value: variance explained by variable/total species variance X 100. Each variable tested individually and then combined. Forward selection of variables option was chosen to test significance of environmental variables. Variables with $p < 0.05$ are included in the model. Superscript indicates order of inclusion in the model.

	All bryophytes		Mosses		Liverworts	
	Individual	Model	Individual	Model	Individual	Model
Latitude (°east)	31.0***	31.0^{1}***	32.0***	32.0^{1}***	24.0***	6.0^{4}*
Altitude (m)	28.0***		23.0***		23.0***	
Aspect (°)	10.0*		11.0*	10.0^{2}**	11.0**	
Mean annual temperature (°C)	31.0***	12.0^{2}**	27.0***		26.0***	26.0^{1}***
Mean annual rainfall (mm)	2.0	8.0^{3}*	3.0		2.0	
Rainfall driest month (mm)	14.0**		13.0**		11.0*	
Slope (°)	7.0		9.0*		3.0	
pH	6.0	6.0^{4}*	4.0		5.0	7.0^{3}*
Total Nitrogen (%dry soil weight)	2.0		3.0		2.0	
Available Phosphorus (ppm)	3.0		5.0		1.0	
% Cover of above ground substrates	5.0		9.0*		3.0	
% Canopy cover	2.0		4.0		4.0	
Nº of substrate types per site	12.0**		11.0**		8.0	
Basal area of *Eucalyptus* spp. (m^2 ha^{-1})	5.0		3.0		4.0	
Basal area of rainforest species (m^2 ha^{-1})	7.0		4.0		10.0*	
Basal area *of Dicksonia antarctica* (m^2 ha^{-1})	11.0**	7.0^{5}*	11.0*	6.0^{3}*	11.0*	10.0^{2}*
Basal area of dead trees (m^2 ha^{-1})	6.0		2.0		6.0	
Carbonate	4.0		5.0		2.0	
Igneous	6.0		1.0		8.0*	
Siliceous	5.0		1.0		6.0	

Discussion

Bryophytes contribute significantly to the biodiversity of old growth mixed forest, with 202 species (115 liverwort and 87 moss species) recorded. This total constitutes approximately one third of the total bryophyte flora for Tasmania (Dalton *et al.* 1999) and is comparable to that recorded in a cool temperate rainforest study (144 liverwort and 87 moss species, (Jarman and Kantvilas 1995b). There were 32 liverwort species and 37 moss species found in the present study of old growth wet eucalypt forest that were not recorded from rainforest (Jarman and Kantvilas 1995b). Other studies have also found a greater number of liverwort than moss species in the wettest of habitats (La Roi and Stringer 1976; Gradstein *et al.* 1989; Pharo and Beattie 1997).

Of the environmental variables, mean annual temperature, altitude, rainfall of the driest month and aspect were most significant in predicting variation in bryophyte richness. Bryophytes thrive in moist environments and liverworts, in particular, are more prevalent in the more moist and cooler habitats The greater richness of old growth mixed forest bryophytes as aspect becomes more sheltered may be a relict of variation in fire disturbance rather than associated with light levels. Forest somewhat protected from fire include patches on southerly aspects, sites on more fertile soil (Jackson 1968) or with a callidendrous rainforest component (Jarman *et al.* 1991).

The number of substrate types at a site appears to be a good predictor of bryophyte species composition and, in particular, moss species composition. A study in wet eucalypt forest of northeast Tasmania also found that bryophyte species richness and composition was correlated with the number of substrates at a site (Pharo and Blanks 2000). Many studies have described bryophytes as being associated with particular substrates (Schmitt and Slack 1990; Söderström 1993; McAlister 1997; Rambo and Muir 1998a; Qian *et al.* 1999; Pharo and Beattie 2002). An association with species richness and species composition is therefore not surprising.

Canopy cover was not a significant predictor of bryophyte species richness or composition. Previous studies have found the dense canopy of temperate forests important in determining light levels for plant growth in the understorey (Kantvilas and Minchin 1989; Specht and Specht 1993). The negligible effect of canopy cover on bryophyte diversity, within the range recorded in this study, may be due to the low

angle of altitude of the sun in these forests. Little radiation into these forests may promote a moist environment that is likely to favour bryophyte growth.

Nutrients, such as nitrogen and phosphorus, have been suggested to be more important to vascular plants than bryophyte species (Økland and Eilertsen 1994). Substrates (including ground) of mixed forest were found to have higher rates of acetylene reduction (nitrogen fixation) than the associated bryophytes (Brasell *et al.* 1986). The present study also found no relationship between soil nutrients and bryophyte species richness and composition. pH explained a small amount of variation in bryophyte species composition once variation due to latitude, mean annual temperature and mean annual rainfall were accounted for. The poor relationship between bryophyte species composition and nutrients in the soil may be due to a tendency in bryophytes for nutrient uptake to take place across the plant surface from the air, rather than via roots (Crum 2001).

The large number of species found in old growth mixed forest demonstrates that bryophytes contribute substantially to biodiversity in old growth mixed forests. In particular, liverworts are major contributors to bryophtye diversity, especially in forests of southern Tasmania. The importance of substrates for bryophyte presence is demonstrated where bryophyte and moss species richness are significantly positively correlated with percentage cover of above ground substrates, and liverwort species richness is positively correlated with the number of substrate types per site. Old growth mixed forest is therefore not only an important refuge for vascular plants (Hickey 1994) but also for many bryophyte species which exist on these vascular plant substrates.

Chapter Three

Successional sequences of bryophytes in mixed forest, Tasmania

Abstract

Fire is the major agent of disturbance in mixed forests. Whereas succession and vital attributes of vascular plants in these forests are well documented in the literature, there is little equivalent information regarding bryophytes. In this chapter, bryophyte species were recorded from 105 sites. These sites were analysed after division into three age class groups; a (1 – 18 years since disturbance), b (31 – 67 years) and c (> 110 years). Sites dominated by Eucalyptus regnans *and* E. obliqua *were also analysed by age class. These data sets were used to investigate bryophyte species succession from early aged forest through to old growth mixed forest. 107 mosses and 133 liverworts were found overall. This included 90 species in age class a (52 mosses, 38 liverworts), 207 species in age class b (96 mosses, 111 liverworts) and 202 species in age class c (87 mosses, 115 liverworts). A number of species were found only in one age class. Age class b and c had similar numbers of totally faithful species. More liverwort than moss species were exclusive to age class c forest. Many species that frequently occurred in age class a forest were not found in older forest. In contrast, some species that occurred in age class b forest were also found in age class c forest. The exclusive occurrence of the epiphytic mosses* Neckera pennata *and* Calyptopogon mnioides *in age class b forest is strongly associated with the presence of* Pomaderris apetala *and* Acacia dealbata *trees. Liverwort species dominated age class c forest, where the basal area of rainforest species was significantly greater than in other forest ages. There is a substantial lack of information regarding vital attributes of bryophyte species in wet eucalypt forests. Research into bryophyte function and reproduction in different forest stages would provide valuable insight into the resilience and/or resistance of species to disturbances such as fire.*

Introduction

The importance of bryophytes in the early stages of succession in forest ecosystems has long been recognised (Southorn 1976; Duncan and Dalton 1982; Longton 1992). Some acknowledgment has been given to their ecological role and function in mature communities (Söderström 1988a; Hansen *et al.* 1991; Qian *et al.* 1999; Vellak and Paal 1999) but overall little is known of their successional roles (Muhle and LeBlanc 1975; Crites and Dale 1998; Boudreault *et al.* 2000). The classical view of succession is that, following disturbance, species assemblages occupy a site and with time they give way to new species until eventually the community is able to reproduce continually (Clements 1916). This concept has little application where disturbance is a regular event. A vegetation climax cannot be predicted with certainty because temporal and spatial variation and even initial floristics may influence the composition, structure and function of the developing community (Egler 1954; Connell and Slatyer 1977). Noble and Slatyer (1980) plausibly indicated that the pattern of succession depends not only on the type of disturbance but also life history traits or 'vital attributes' of a species. This assumes substantial knowledge is available regarding the autecology of species, which, for most bryophyte species in Australia, is somewhat limited.

Fire is the principle agent of disturbance in the mixed forests of Tasmania. Tasmanian mixed forest is defined as vegetation with a rainforest understorey and eucalypt overstorey (Gilbert 1959). The term 'wet eucalypt forest' includes both mixed forest and forests with broad-leaved shrubs and/or ferns dominant in the understorey (Kirkpatrick *et al.* 1988). Fires maintain mixed forest at intervals of 100 - 350 years (Gilbert 1959; Jackson 1968; Mount 1979; Hickey 1994). In classical successional terms, in the absence of disturbance, sedgelands progress to shrublands, then to a wet eucalypt forest community, to mixed forest and if there is still an absence of disturbance (i.e. fire after approximately more than 400 years) eucalypts die out, leaving rainforest (Jackson, 1968).

A number of factors may affect the ability of bryophytes to successfully establish after disturbance including severity/intensity of disturbance, competition, substrate availability (for example woody debris and vascular species), propagule availability, vital attributes and environmental conditions. The vital attributes of the rainforest and

Eucalyptus species of mixed forest are largely known (Read 1999; Wells and Hickey 1999). Patterns of succession or replacement sequences for mixed forest vascular species based on recurrent fire disturbances have been derived, albeit inaccurately (Noble and Slatyer 1980). For bryophytes, initial succession in mixed forest after fire disturbance has been well documented, with bryophytes considerably modifying the environment (Cremer and Mount 1965; Duncan and Dalton 1982; Brasell and Mattay 1984; Hill and Read 1984; Brasell *et al.* 1986). Species such as *Ceratodon purpureus, Barbula calycina, Funaria hygrometrica, Marchantia berteroana* and *Polytrichum juniperinum* have recorded from these studies as efficient soil colonisers. In northern hemisphere forests, *C. purpureus*, *F. hygrometrica* and *P. juniperinum* have also been similarly recorded in initial post-disturbance conditions, along with *Marchantia polymorpha* (Longton 1992). However, unlike in eucalypt forests, lichens dominate the post-disturbance ground layer of boreal forests (Foster 1985). In early successional forest, bryophytes appear to transform environmental conditions, for example, by encouraging or discouraging seed germination and establishment (Cremer and Mount 1965; During and van Tooren 1990). Jonsson and Esseen (1998) contrasted the role of vital attributes in succession of bryophytes and vascular plants in patches of disturbance in old growth boreal forest. They suggested the more rapid recolonisation by bryophytes than vascular plants of disturbed old growth forest soil patches was perhaps due to contrasting regeneration methods.

Although there are numerous records of bryophyte species in wet eucalypt forest communities (Ashton 1986; Jarman and Kantvilas 1994; Blanks 1996; Turner 1996; Pharo and Beattie 1997; Pharo and Blanks 2000; Jarman and Kantvilas 2001a) none investigated successional stages that occur within communities. Elsewhere, in the trembling aspen forests of Alberta, temporal differences in bryophyte assemblages on coarse woody debris were attributed to the successional stages or different ages of the forest (Crites and Dale 1998). Also in trembling aspen forests, Boudreault *et al.* (2000), in a survey of epiphytic bryophytes and lichens, found stands representing successional stages had different species associations with a greater number of species found more exclusively or frequently in older stands. Clear temporal stages in bryophyte ground layers have been identified in northern forest of Northern America, beginning with *Marchantia polymorpha* in early stages to *Dicranum* spp. and *Sphagnum* spp. in later stages when the tree canopy has re-established (Heinselman 1981).

A chronosequence approach, such as used in the present study for studying succession of bryophyte species in different stands of forest of different ages has its limitations. A chronosequence fundamentally assumes that by examining multiple stand ages at the same time, results will be similar to those acquired from monitoring a suite of stands over time. Ideally, a stand monitored over time would provide the most accurate results. For bryophytes this is difficult and not practical for a number of reasons. Bryophytes are slow developers; plots would need to be set up and monitored for > 100 years for results. As a number of studies have already investigated early (< 10 years) bryophyte succession in mixed forest (Cremer and Mount 1965; Duncan and Dalton 1982; Hill and Read 1984), there is little interest in immediate results. Current silviculture rotations for mixed forest are 90 years (Whiteley 1999) and where plots could be monitored in regenerating logging coupes, there is no guarantee they would survive to become old growth mixed forest. Given these difficulties, if sites selected encompass similar histories and little geographic separation, a chronosequence method can be a reasonable option.

This study is the first to investigate bryophyte species succession from early aged wet eucalypt forest through to old growth mixed forest. These questions are addressed: (1) Are any bryophyte species found only in one age class? (2) Is there a temporal sequence in the appearance and disappearance of bryophyte species for (a) all sites? (b) *Eucalyptus regnans* dominated forest (c) *E. obliqua* dominated forest?

Materials and Methods

Study area

Data were collected from 105 sites (Figure 3.1), including 69 sites that were sampled earlier by Hickey and Savva (1992) in a vascular plant study. These original sites were not permanently marked but were approximately relocated using grid references. Many original old growth mixed forest sites had been disturbed and additional sites were found using the methods of Hickey (1994). For further details on site selection see Chapter 2. Sites in the northwest were dominated by *Eucalyptus obliqua* and *E. brookeriana* as a co-dominant. In the central forest *E. regnans* was dominant with occasional *E. obliqua* as co-dominant. The southern forests were dominated by *E. obliqua* with *E. delegatensis* or *E. regnans* sometimes co-dominating. Mean annual

temperature ranges from 6.1 to 12.1 °C (mean 9.86 ± 0.15 °C) and mean annual rainfall ranges from 1104 to 2104 mm (mean 1471.21 ± 18.31 mm). Site characteristics, rainfall and temperature data are given in Appendices 8.1 and 8.2.

The 105 sites included 17 sites regenerating after clearfelling between 1983 and 1998, 26 sites regenerating from clearfelling between 1961 and 1969, 1 site burnt by wildfire in 1995, 24 sites burnt by wildfire between 1961 and 1967, 4 sites burnt by wildfire in 1934 and 33 sites of old growth mixed forest (at least 110 yrs old).

Vegetation sampling

For details of vegetation sampling refer to Chapter 2. Nomenclature follows Dalton *et al.* (1991) for mosses, Ratkowsky (1987) for liverworts and Buchanan (1999) for vascular plants except where authorities are given.

Environmental variables

Environmental variables included % cover of above ground substrates and basal area of: all vascular plants, rainforest trees (as defined by Jarman *et al.* 1991) (Appendix 8.3); *Eucalyptus* spp.; *Dicksonia antarctica,* and dead trees (m^2 ha^{-1}, Bitterlich wedge method, Mueller-Dombois and Ellenberg 1974). Measurements were recorded from each of the three transects however, a mean value was used in analyses. Above ground substrates included vascular plant species, logs (greater than 10 cm diameter), fallen branches (less than 10 cm diameter), rocks, roots, dead trees, stumps, upturned root bases and *Dicksonia antarctica* (Treeferns). Treeferns were recorded in three states; alive (vertical stands only), fallen (horizontal and dead) or stumps (vertical and dead). Details of variables are given in Appendices 8.1 and 8.2

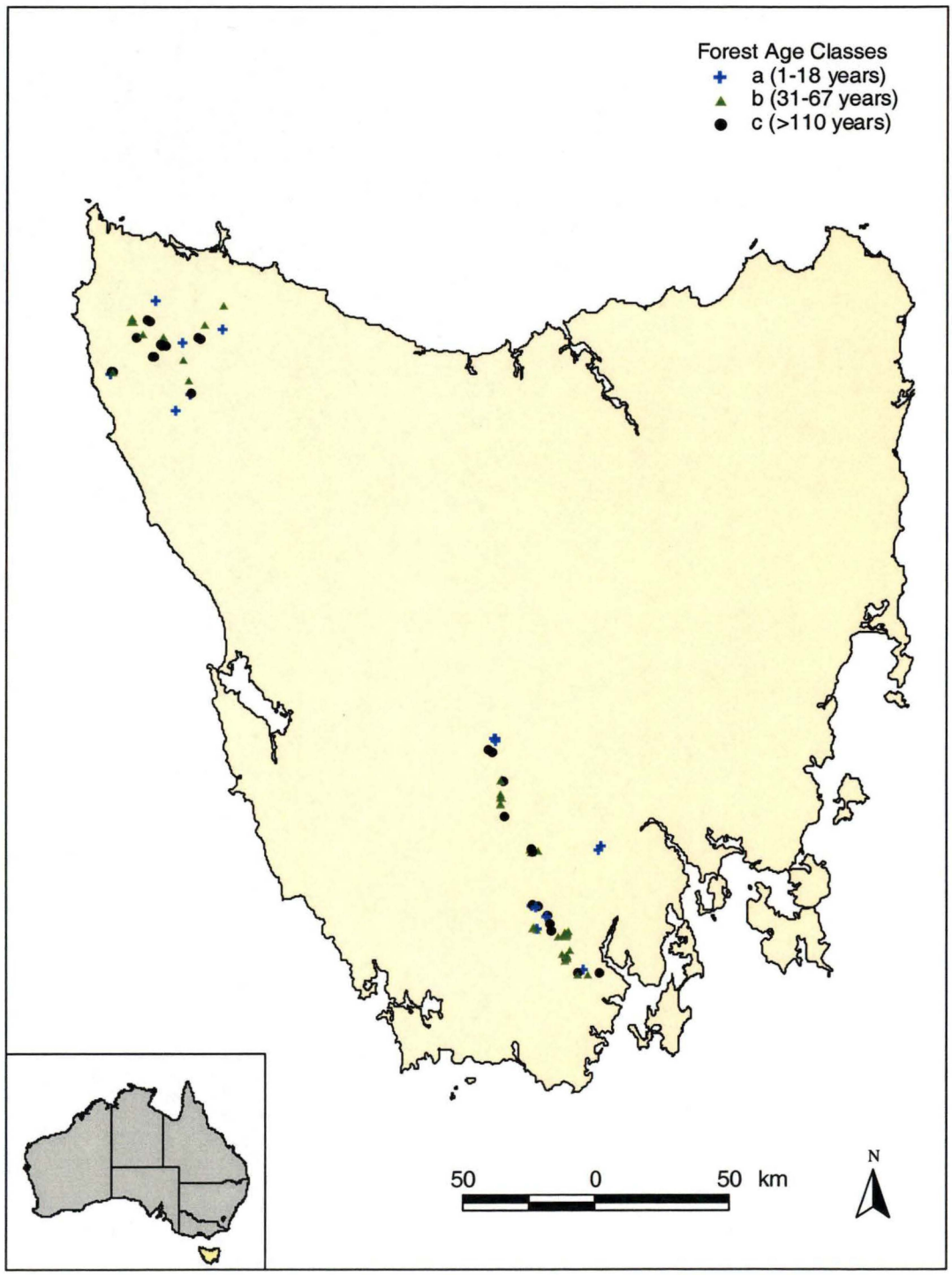


Figure 3.1. Location of 105 study sites in Tasmanian wet eucalypt forest.

Analysis

The presence/absence of bryophyte species from sites and all site variables were entered into the database package DECODA (Minchin 1990). Sites were grouped into age classes since last disturbance. The classes were; a = 1 – 18 years, b = 31 – 67 years, c = > 110 years. Site variables included age class (a, b or c), age of site (years), dominant *Eucalytpus* species, and environmental variables as defined above (Appendix 8.2).

Due to the large amount of data (240 species by 105 sites), trends in species frequency with increasing age of sites were summarised by calculating mean the percentage frequency of each species in groups within age classes along the age variable. Species occurring in less than 5 sites were excluded and remaining species were ordered by their weighted average along the age variable using DECODA (Minchin 1990).

Ordered tables were used to summarise the temporal distribution of bryophyte species in sites dominated by *E. regnans* or *E. obliqua*. For each data set, sites were arranged by increasing age and species ordered by their weighted average along the sample variable age, using DECODA (Minchin 1990). The significance of the associations between individual bryophyte species and age classes was determined using chi square in all cases where expected values were ≥ 5.

Analysis of variance (ANOVA) was used to compare the mean cover of substrate types and basal area of vascular species for age class groups. Tukeys test was used to denote different means at the 95% confidence interval.

Results

From the 105 sites sampled a total of 240 bryophyte species (107 mosses, 133 liverworts) were found. Within each age class group this included; age class a: 90 species (52 mosses, 38 liverworts), age class b: 207 species (96 mosses, 111 liverworts) and age class c: 202 species (87 mosses, 115 liverworts). A number of species were found to occur only within one age class group (Table 3.1). Five species were found only in age class a; *Bryum pseudotriquetrum*, *Grimmia trichophylla*, *Pohlia* spp., *Sphagnum falcatulum* and *Marchantia berteroana*. Of these five species, four were singletons. *M. berteroana* was found at 61.11% of sites. Age class b had 28 unique species, including 16 liverworts (9 singletons) and 12 mosses (6 singletons). The

epiphytic mosses (see Chapter 5), *Neckera pennata* and *Calyptopogon mnioides* were frequent in this age class (9.30% and 11.11% of sites respectively). However, the most common species for this age class was a liverwort, *Chiloscyphus latifolius* (18.52%). Of the 26 species only found in age class c, the majority (19 species) were liverworts with 8 occurring as singletons. Only one of the 26 species, *Pallavicinia lyelli*, is a thallose liverwort. The leafy liverworts, *Adelanthus bisetulus*, *Paraschistochila tuloides*, *Plagiochila circinalis* and *P. radiculosa* are found frequently only in older aged forest.

Species distribution along the age variable is shown in Table 3.2. Species that occur in age class a forest but do not successfully continue into older forest include: *Marchantia berteroana, Barbula calycina, Ceratodon purpureus, Cephaloziella exiliflora, Funaria hygrometrica, Polytrichum juniperinum, Racomitrium crispulum* var. *tasmanicum* and *Cephaloziella hirta*. Many species are dominant in both age class b and c forest, for example *Plagiochila fasciculata, Heteroscyphus billardieri, Chiloscyphus echinellus, Fissidens pallidus, Weymouthia mollis and Trichocolea mollissima*. Liverwort rather than moss species, are dominant in older forests.

Table 3.1. Species that occur in only one age class. Number of sites (n) in age class: age class a, n = 18, age class, n b = 54, age class c, n = 33, L = liverwort, M = moss.

Age class a		Number of occurrences	Age class b		Number of occurrences	Age class c		Number of occurrences
Marchantia berteroana	L	11	*Chiloscyphus multipennus* aff.	L	1	*Cheilolejeunea albovirens*	L	1
Bryum pseudotriquetrum	M	1	*Chiloscyphus rupicolus* (Steph.) Engel & Schust.	L	1	*Cheilolejeunea cambelliensis*	L	1
Grimmia trichophylla	M	1	*Frullania pentapleura*	L	1	*Chiloscyphus bispinosus*	L	1
Pohlia sp. a	M	1	*Heteroscyphus argutus*	L	1	*Diplasiolejeunea plicatiloba*	L	1
Sphagnum falcatulum	M	1	*Heteroscyphus* sp. a	L	1	*Frullania monocera*	L	1
			Kurzia sexfida	L	1	*Heteroscyphus biciliatus* (Hook.f. &Tayl.) Engel	L	1
			Plagiochila fuscella	L	1	*Lejeunea* spp.	L	1
			Radula retroflexa	L	1	*Lepidozia pendulina*	L	1
			Riccardia colensoi	L	1	*Marsupidium setulosum*	L	2
			Isotachis intortifolia	L	2	*Pallavicinia lyellii* (Hook.) Gray	L	2
			Psiloclada clandestina	L	2	*Paraschistochila pinnatifolia*	L	2
			Heteroscyphus triacanthus	L	3	*Schistochila tasmanica*	L	2
			Treubia tasmanica	L	4	*Cryptochila grandiflora*	L	3
			Lepidozia obtusiloba Steph.	L	5	*Acromastigum mooreanum*	L	4
			Chiloscyphus pallidus	L	7	*Drepanolejeunea aucklandica*	L	4
			Chiloscyphus latifolius (L) Engel & Schust.	L	10	*Adelanthus bisetulus*	L	6
			Brachythecium paradoxum	M	1	*Plagiochila circinalis*	L	7
			Campylopus clavatus	M	1	*Plagiochila radiculosa*	L	7
			Orthodontium sp. a	M	1	*Paraschistochila tuloides*	L	10
			Pohlia nutans	M	1	*Anastrophyllum schismoides*	M	1
			Pyrrhobryum parramattense	M	1	*Distichophyllum rotundifolium*	M	1
			Rhizogonium pennatum var. *aristatum*	M	1	*Rosulabryum capillare* (Hedw.) Spence	M	1
			Brachythecium salebrosum (F. Weber & D. Mohr) Schimp.	M	2	*Sematophyllum uncinatum*	M	1
			Ptychomitrium australe	M	2	*Holomitrium perichaetiale*	M	2
			Calyptrochaeta apiculata	M	4	*Calyptrochaeta brownii* (Dix.) J.K. Bartlett	M	3
			Rhynchostegium tenuifolium	M	4	*Sphagnum australe*	M	3
			Neckera pennata	M	5			
			Calyptopogon mnioides	M	6			

Table 3.2. Mean percentage frequency of selected species in all sites within age class groups. Species are listed in order of their frequency in age class groups in increasing order along the age variable. A dash indicates species is missing from a segment. Number of sites (n) in age class: age class a, n = 18, age class b, n = 54, age class c, n = 33, L = liverwort, M = moss.

Age class		a	a	a	b	b	b	b	b	b	b	b	b	c	c	c	c	c	c
N° sites per age class group		6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	5	5	5
Marchantia berteroana	L	0 8	0 7	0 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Barbula calycina	M	0.8	0.8	0.8	-	-	-	0.5	-	-	-	-	-	-	-	-	-	-	-
Ceratodon purpureus	M	1.0	1 0	1 0	-	-	-	0.2	-	-	-	-	-	-	-	0 2	-	-	-
Cephaloziella exiliflora	L	0 3	0 8	1 0	-	-	0.5	0 3	-	0.2	0 2	-	-	-	-	-	-	-	-
Funaria hygrometrica	M	1.0	0.5	0.8	-	-	-	-	-	-	0.2	-	-	0 3	-	-	-	-	-
Polytrichum juniperinum	M	1 0	1.0	1 0	-	-	0.2	1 0	0.2	0 2	0 2	0.3	-	0.2	-	-	-	-	-
Racomitrium crispulum var. *tasmanicum*	M	-	-	0 5	-	-	0 2	0.3	-	-	0.2	-	-	-	-	-	-	-	-
Cephaloziella hirta	L	-	0.3	0.5	-	-	-	-	-	-	-	0.2	-	-	-	0.2	-	-	-
Lepidozia obtusiloba Steph.	L	-	-	-	-	0.2	0.3	0 2	-	0 2	-	-	-	-	-	-	-	-	-
Chiloscyphus latifolius (L) Engel & Schust.	L	-	-	-	-	-	0 7	-	0 2	0.3	-	0 3	0.2	-	-	-	-	-	-
Campylopus introflexus	M	1.0	1.0	1.0	0.2	0.2	0.2	0.7	0.2	0.2	0 2	0.3	-	0.7	0.2	0.3	-	-	0.2
Calyptopogon mnioides	M	-	-	-	-	-	0 2	-	-	-	-	0 5	0 3	-	-	-	-	-	-
Neckera pennata	M	-	-	-	-	-	-	-	-	-	-	0.5	0.3	-	-	-	-	-	-
Chiloscyphus pallidus	L	-	-	-	0 2	0.3	0.2	-	-	0.2	-	0.2	0 2	-	-	-	-	-	-
Ulota viridis	M	0 2	-	-	-	-	0.2	0.3	-	0.2	-	0 3	-	-	-	-	-	-	0 2
Racopilum cuspidigerum (Schwägr.) Ångstr. var. *convolutaceum* (Müll Hal) Zant. & Dijk.	M	-	-	-	0 3	0.7	0.5	0 3	0 5	0.2	0.2	0.5	0.3	-	-	0.2	-	0.2	-
Acrocladium chlamydophyllum	M	0 2	-	0.2	-	0 3	0.7	0.5	0.5	0.2	-	0 8	0.3	-	-	0 2	-	0 4	-
Sematophyllum subhumile var. *contiguum* (Mitt) Tan, Schofield & Ramsay	M	-	-	-	0 2	0.5	-	0 2	0 2	0 2	-	0.2	0 2	-	0.2	-	-	-	-
Frullania proboscıphora	L	-	-	-	0.2	0 2	0.5	0.2	-	0 2	0.2	0 8	0.2	-	0 2	0 2	-	-	-
Chiloscyphus villosus	L	-	0.2	0.3	-	-	0.2	-	-	0.2	-	0.2	0.2	-	0.2	-	-	0.2	-
Lepidozia concinna	L	-	-	-	-	-	0 3	0 3	0.2	-	-	-	-	-	-	-	-	0.2	-
Ditrichum difficile	M	-	-	-	0.2	0.2	0 5	0 5	-	-	0 2	0 2	-	-	0 2	0 2	-	-	-
Chiloscyphus semiteres	L	0.3	0 8	0 8	0 8	0 8	0.7	1.0	0 8	0.3	0.7	0.8	0.5	0 7	0 7	0 3	0.6	0.4	0.4
Sauloma tenella	M	-	-	-	0.2	0.2	-	0 2	-	-	-	-	0.2	0.2	-	-	-	-	-
Riccardia cochleata	L	-	0.2	0 5	0.5	1.0	0 8	0 7	0.7	0.3	0 3	0.3	0.5	0.3	-	0.8	0 2	0.2	0 2
Fissidens pungens	M	-	-	-	-	0 2	0.2	0.2	0 2	0 2	-	0 5	-	-	0 2	0 2	-	-	-
Rosulabryum billardieri var *billardieri* (Schwägr) Spence	M	0 2	0.3	0.7	0.7	1.0	0.8	0.5	0 7	1.0	0.3	0.8	0.3	0.5	0 5	0.3	0.2	0.8	0.4
Kurzia compacta (Steph.) Grolle	L	0 2	-	0.3	-	1.0	0 8	0.8	0.5	0.3	0 2	0.2	0 5	0.3	0.2	0.5	0.2	0.2	-
Campylopus pyriformis	M	-	-	0 2	-	0 3	-	0 2	-	-	-	0 2	-	-	-	-	0.2	-	0 2
Chiloscyphus bispinosus aff.	L	0.2	-	0 2	-	-	0.2	-	-	-	-	-	-	0.2	-	0 2	-	-	-
Orthodontium lineare	M	0 2	0 2	0.3	0 7	0.7	0.8	0.3	0 7	0.5	0.3	0.8	0.8	0.2	0.3	0.5	0.6	0.2	0.4
Thuidium sparsum	M	0 2	-	0.2	0.2	0.5	0 5	0.5	0.8	0.2	0.3	0.5	0.3	-	-	0.3	-	0.8	0.6
Isopterygium limatum	M	-	0 2	-	-	0 7	0 2	0.2	0.3	0.7	0 3	0.5	0 2	0.2	-	0.3	0.4	0 2	-
Riccardia spp	L	-	-	-	-	-	0.7	1 0	0.2	0.5	0 2	-	-	0.3	0 2	0 3	-	-	-
Riccardia crassa	L	-	-	0 3	0.3	0.8	0.7	0.5	0.8	0 7	0.3	0 7	0.5	0.5	0 2	0.3	0 2	0.8	-
Orthotrichum tasmanicum var. *tasmanicum*	M	-	-	-	-	0.3	0.5	0.2	0.3	-	-	0.7	-	-	0 2	0.3	-	-	0.2
Thuidium furfurosum	M	-	-	-	0.2	0 5	0.5	-	0.2	0 2	0 2	0.5	0.3	-	-	0.5	-	0.4	-
Dicranoloma robustum var. *setosum*	M	0.3	0 2	0 5	0.5	1.0	1.0	1.0	0.8	0 5	0 3	1 0	1.0	0.3	0 7	0 8	0 4	1 0	0 6
Frullania falciloba	L	0.3	0 3	0 3	0 2	0.3	0.7	0.5	0 5	0.2	0.3	0 7	0 5	0.5	0.3	0 5	0 2	0.6	0.6
Kurzia hippurioides	L	-	-	0.5	0.2	0.5	0 8	1 0	1.0	0.5	0.3	0 2	0.7	0 3	-	0.8	0 2	0.2	1.0
Pyrrhobryum mnioides	M	-	-	-	-	0 3	0.3	0 2	0.2	0.3	0.2	-	-	-	-	0 2	0.4	0.2	-
Dicranoloma dicarpum	M	0.2	0.3	0 2	0.7	0 3	0.8	0.8	0.7	0.3	0 7	0.8	0 8	0.3	0.5	0 5	0.8	0 8	0 4
Plagiochila retrospectans	L	-	-	-	-	0.2	0.2	0.7	0.3	0 2	-	-	0 3	-	-	0.3	0 2	0.2	0.2
Temnoma townrowii	L	-	-	-	0.2	0.3	-	0.2	0.5	0 2	0 3	0 2	-	-	0 5	-	0 2	0.2	-
Ptychomnion aciculare	M	0.2	0.8	0.7	1.0	1.0	1 0	1 0	1 0	1.0	1.0	1 0	1.0	1 0	1 0	1.0	1.0	1.0	1.0
Dicranoloma billardieri	M	0 3	0 8	0 5	1.0	1 0	0.7	1.0	1 0	1.0	0.7	0 8	1.0	1.0	1.0	1.0	1.0	1.0	0 6
Macromitrium archeri	M	-	0.2	-	0.7	0.7	0.3	0.2	0.5	0.5	0 3	0.5	0.8	0.5	0.2	0 8	0.4	0.2	-
Zygodon intermedius	M	-	0.2	0.2	0 5	0.7	0.7	0.3	0.3	0.3	0 2	0.5	0.5	0.2	0.2	0 7	0.4	0.4	0.6
Lejeunea drummondii	L	-	-	-	0.5	0.8	0 3	0.3	0.7	0.7	0.8	0.5	0 5	0 7	0 3	0 5	0 8	0.2	-
Bazzania involuta	L	0 2	0 7	0.7	1 0	1.0	1 0	1.0	1.0	1 0	1.0	1.0	1.0	1.0	1 0	1.0	1.0	1.0	1 0
Lepidozia ulothrix	L	0 3	0 5	0.7	1.0	1 0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1 0	1.0	1.0	1.0	1.0

Age class		a	a	a	b	b	b	b	b	b	b	b	b	c	c	c	c	c	c
N° sites per age class group		6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	5	5	5
Chloscyphus leucophyllus	L	-	-	-	0 3	0 3	0 3	0 5	0 5	0.2	0.2	-	-	0.3	-	0.2	0.4	0 2	0.2
Leptotheca gaudichaudii	M	0.2	0 7	0.7	1.0	1.0	1 0	1 0	0.8	0.7	1 0	1 0	0.8	1.0	1.0	1 0	1.0	0 8	1 0
Rhaphidorrhynchium amoenum	M	0 2	0.7	0 5	1 0	1 0	0.8	1.0	1.0	1.0	1 0	1.0	1 0	1.0	1 0	1.0	0 8	1 0	1.0
Plagiothecium lamprostachys (Hampe) Jaeg.	M	-	-	-	0.3	0.5	0 5	0 2	0 5	0.3	0.5	0 8	0.3	0.2	0.3	0 3	0 8	0.2	0 4
Ulota lutea	M	-	-	-	-	-	0 2	0 5	-	-	-	0 2	0.2	-	-	0.3	-	-	0 2
Trachyloma planifolium	M	-	-	-	-	0.2	0 2	-	-	-	-	0 2	0 2	0.2	0 2	-	-	-	-
Heteroscyphus coalitus	L	-	0 2	0.2	1.0	1.0	0.8	0 7	1.0	1.0	1.0	1.0	0 8	0 8	1 0	0 8	1.0	0.6	0 4
Fissidens tenellus	M	-	-	-	0 3	1.0	0.3	0.3	0 8	0.7	0.5	0.3	0 3	0.3	0.5	0.3	0 6	0 4	0.4
Chiloscyphus muricatus	L	-	0 2	0.3	0.5	0 7	0.3	0 3	0.3	0.5	0 8	0.3	0 3	0.5	1 0	0.5	0.4	0.2	-
Dicranoloma robustum	M	-	-	0 2	0 3	0 3	0.7	1.0	0 8	0.3	0 8	0.5	0.5	0.7	-	0.3	0 6	0.6	0.8
Brachythecium salebrosum/ rutabulum	M	-	-	-	0.2	0 5	0.3	-	-	0 2	-	-	-	0 2	-	0 5	-	-	-
Rhizogonium novae-hollandiae	M	0 3	0.2	0 5	0.8	1 0	1.0	1.0	1 0	0.8	0 8	1 0	1 0	1.0	0.8	1.0	1.0	1 0	1.0
Lopidium concinnum	M	-	-	0.2	0.5	0 8	0.3	0 5	0.8	0.7	0.5	0 7	0.5	0 3	0.5	0 3	0.8	1.0	0.4
Warburgiella leucocytus (Mull Hal.) Tan, Schofield & Ramsay	M	0.2	0.2	0 3	0.7	1 0	1.0	1.0	1.0	0 7	0 7	1 0	1.0	1.0	0.8	1.0	0.8	0 6	1.0
Heteroscyphus fissistipus	L	0 2	0 5	-	1.0	1.0	0 7	0.5	1 0	1.0	1 0	1.0	0.7	1.0	1 0	1.0	1.0	1.0	0 4
Wijkia extenuata	M	0.2	0 3	0 5	1.0	1 0	1.0	1 0	0.8	0 8	0 7	1 0	1.0	1.0	1.0	1 0	1.0	1 0	1.0
Atrichum androgynum	M	-	-	-	0.3	0.2	-	-	-	0 2	0.3	-	0 3	0.2	-	-	0 2	0.4	-
Hypnum cupressiforme	M	0 3	0.3	0 5	0.7	0 7	0.7	0.5	0.8	0 8	0 8	1 0	0.8	1.0	1.0	1.0	0.6	0.8	1 0
Dicranoloma menziesii	M	-	0 5	0.5	1.0	0.8	1 0	0.7	1.0	1 0	1.0	0.7	0 8	1.0	1 0	1 0	1.0	1.0	1.0
Catagonium nitens (Brid.) Cardot ssp. *nitens*	M	-	-	0 2	-	0 2	0 2	0 5	0.3	0.2	-	-	-	-	-	0 3	-	0.6	0 2
Rhizogonium distichum	M	0 2	0.2	-	0 8	0.7	0.2	0.2	0 5	0 5	0 7	0.8	0.7	0.7	1.0	0.3	0 8	-	0.6
Zoopsis argentea	L	-	0.3	0.3	0.7	1.0	1.0	0 8	0.8	1.0	1.0	0.8	1 0	1.0	1 0	0 8	1.0	1.0	1 0
Weymouthia cochlearifolia	M	0 3	0.2	0 2	0 3	0.5	0 3	0.2	0 3	-	0 3	0 3	0.5	0.2	0.5	0.7	0 2	0.6	0.6
Frullania clavata	L	-	0 2	-	0.5	0.7	0.3	0.2	0 7	0.7	0.8	0.7	0 8	0.5	0 7	0 7	0.4	0.6	0.6
Telaranea patentissima	L	-	0 2	0.3	1.0	1.0	1 0	1.0	1 0	0 8	1.0	0 5	1.0	1.0	1.0	1.0	1 0	1.0	1.0
Distichophyllum pulchellum	M	-	-	-	0 3	0 7	0.2	0 3	0 8	0.5	0.2	0.3	0.7	0.3	-	0.7	0.2	0.8	0 4
Mittenia plumula	M	-	-	-	0.5	0.3	0.3	0.3	0 2	0 3	0.3	0 2	-	0.5	0.2	0.3	0 4	0 4	-
Pallaviciniaceae	L	-	-	0 2	0 3	0 2	-	0.2	0 2	-	0.3	-	-	0 2	0.5	-	0 2	-	0.2
Achrophyllum dentatum	M	-	0 2	-	1.0	0.8	0 3	0.3	0.5	0.8	0.8	1.0	0 5	0.8	1 0	0.7	0 8	1.0	0 2
Plagiochila incurvicolla	L	-	-	-	-	0 2	-	-	0 2	0 2	-	-	-	0 2	-	0.2	-	-	-
Gackstroemia weindorferi	L	-	0.2	-	0.8	0 5	0.7	1.0	1 0	0.8	0.7	0.3	0.3	0.3	0.8	1 0	0.6	1.0	0.8
Metzgeria decipiens	L	-	0 2	-	1 0	0.8	0 5	0.7	1.0	1 0	0 8	1 0	0 8	1.0	0 8	0.8	0 8	1 0	1.0
Dicranoloma platycaulon	M	-	0.2	-	0 2	0 7	0.3	0 2	-	0.2	0 2	0.2	-	0.5	0.3	0.3	0.4	-	-
Balantiopsis diplophylla	L	-	0 2	-	0.7	0.8	0 3	0.5	1.0	0.5	0.7	-	0 3	0.5	0 5	0.7	0.4	1.0	0 6
Kurzia hippurioides aff.	L	-	-	0.2	0.7	0.7	0 3	0.8	0 8	0.8	0 8	0 3	0.7	0 8	1.0	0.8	0 6	0.4	0.4
Zoopsis leitgebiana	L	-	-	-	0 3	0.7	0.3	0 5	0 7	0.3	0.3	0.2	-	0 5	0.2	0.7	0.4	0.6	0.2
Cyathophorum bulbosum	M	0.2	-	-	0.8	0.7	0.5	0.3	0.7	0 8	0 8	0 7	0 3	0.7	0 8	0.7	0.8	1 0	0 4
Lepidozia laevifolia	L	0 2	-	0 3	0 7	0 3	0 8	0.5	1 0	0 8	0 5	0.7	0.5	1 0	0.8	1.0	1.0	0.6	0.4
Radula buccinifera	L	-	0.2	-	1.0	0.8	0.3	-	0.8	0.8	0.8	0.2	0 7	0.3	0 8	0.7	1.0	1.0	0 4
Goniobryum subbasilare	M	-	-	-	0.5	0 3	0.3	-	0.3	0 2	0.5	0 2	-	0 2	0.3	0.2	0.8	-	0.4
Campylopus pyriformis var a	M	-	-	-	-	-	0.2	-	-	-	0.2	0.2	-	-	-	0 2	-	0.2	-
Hypnum chrysogaster	M	-	0.2	0.5	0.7	0.7	0.7	1.0	0.7	0.7	0 8	0 7	1.0	1.0	1 0	1.0	1.0	1.0	0.8
Telaranea mooreana	L	-	-	-	0 2	0 5	-	-	0.3	0.3	-	-	-	0.3	0.3	0.2	0.2	-	-
Campylopus bicolor var. *ericeticola*	M	-	-	-	-	-	-	-	-	-	0.2	0.2	0 2	-	-	-	-	-	0 4
Fissidens taylorii	M	-	-	0.2	-	-	0 2	0.2	-	-	-	0 3	0 2	0.2	0.5	0.2	-	-	-
Hampeella alaris	M	0.2	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6
Campylopus purpureocaulis Dusén	M	-	-	-	-	-	-	0 2	0 2	0.2	0 2	-	-	0.2	-	-	-	-	0 4
Riccardia aequicellularis	L	-	-	0.3	0.3	0.7	0 2	0.5	0 2	0 7	0.2	-	0.2	0.5	0.8	0.3	0.4	0.6	0.2
Lembophyllum divulsum	M	0 2	-	-	0 3	0 3	0.8	-	0 2	-	-	0.7	0.3	0 2	0.7	0 5	0 4	0.4	0.4
Leucobryum candidum	M	-	0.2	0 2	0 8	1 0	0.5	0.3	0 2	0.7	0.7	0.2	0.5	1.0	1 0	0.5	1.0	0 2	0 8
Lepidozia procera	L	-	-	-	0.7	0.5	0.8	1.0	0.8	0 7	0.7	0 2	0 7	0.8	1 0	0.7	1.0	0 6	0 8
Podomitrium phyllanthus	L	-	-	-	0 3	0 7	0 3	-	0.7	0.5	0 7	0.2	0.2	0 5	0.3	0 7	0 8	0.4	0.4
Heteroscyphus limosus	L	-	-	-	0 3	0 3	0.7	0.2	-	0.2	0 2	0.5	0 2	0.8	0 2	0.5	-	0 2	0.4
Leptostomum inclinans	M	0.5	0 5	0.3	0.2	-	0 7	0.3	-	0.2	0 2	0 3	0 2	0.5	0.5	0.7	0 6	1 0	1.0
Symphyogyna podophylla	L	-	-	0.2	0.5	0.8	0 2	-	0 7	0 5	0.3	0.3	0.2	0 5	0.8	0 5	0 4	1.0	0 4
Hypnodendron spinnervium ssp *archeri*	M	-	-	-	0.2	0 7	0.2	0.5	0 7	0.5	0.5	0.2	0 7	0 7	0.5	0.5	-	1 0	0.8
Plagiochila fasciculata	L	-	-	-	0.8	0.8	0 2	-	0 5	0 8	0 7	0.2	0 5	0.7	0 8	0.7	0.6	0 6	0.8

Age class		a	a	a	b	b	b	b	b	b	b	b	b	c	c	c	c	c	c
Nº sites per age class group		6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	5	5	5
Heteroscyphus billardieri	L	-	-	-	0 2	0 3	-	0.2	0 2	0 3	0.3	0 2	-	0 5	0.3	0.5	0 2	-	-
Frullania rostrata	L	0 2	-	-	0.3	0.5	0.3	0.7	0.3	0 3	0.8	-	0 7	0 7	0 2	0.8	0.4	0 8	1 0
Hypopterygium didictyon Mull. Hal	M	-	-	-	-	-	-	-	0 2	0.2	-	-	0.2	-	-	0.2	-	0.2	-
Teleranea herzogii (Hodgs) Hodgs.	L	-	-	0 3	0 2	0.2	0.2	-	-	0.2	0 2	-	-	-	0 8	0 2	-	0 2	0 2
Chiloscyphus echinellus	L	-	-	-	0 8	0 5	0 3	0.5	0.7	0.7	0 5	0.8	0.5	0.8	1.0	1.0	1.0	0.6	0.8
Geocalyx caledonicus	L	-	-	-	0 2	-	-	-	0 3	-	-	-	-	-	-	0.2	0 2	0.2	-
Riccardia wattsiana	L	-	-	-	0.2	-	0 2	-	-	0.2	-	-	-	0 2	-	0.3	-	-	-
Heteroscyphus sinosus	L	-	-	-	-	-	0.5	-	0 2	0 2	-	-	-	-	0.3	0 5	-	-	-
Distichophyllum microcarpum	M	-	-	-	0 2	0 2	-	-	0.2	0.2	-	0 2	-	-	-	0 2	-	0 6	0 2
Heteroscyphus conjugatus	L	-	-	-	0.3	-	-	-	0 2	0 2	0.2	-	-	0.3	0.3	0.2	-	-	-
Fissidens pallidus	M	-	-	-	0 5	0.5	0 2	0.2	0 3	0 5	0.7	0 8	0 3	0 5	1 0	0.7	0 4	0 8	0 6
Hypnodendron spp.	M	-	-	-	-	0.2	-	0 2	-	0.3	-	-	-	-	-	0.3	0.2	0 2	-
Radula ratkowskiana	L	-	-	-	-	-	-	0.2	-	-	-	0.2	0.2	0 2	-	0 2	-	-	0.2
Radula multiamentula	L	-	-	-	-	-	-	-	-	0.2	0 2	0.2	-	0 2	-	0.2	0.2	-	-
Glyphothecium sciuriodes	M	-	0 2	-	0.3	0 5	0.3	0.2	0.3	-	0.2	0.2	0.7	0.2	-	0.7	0.8	0.6	1.0
Radula compacta	L	-	-	-	0 2	0.5	-	0.3	0 5	-	0.5	0 5	0 5	0 7	0.3	0 7	0 4	0 6	0.6
Jamesoniella tasmanica	L	-	-	-	0.3	-	-	-	0.2	0.2	0.2	-	0.2	0 7	0.2	0.2	-	-	-
Metzgeria saccata	L	-	-	-	-	-	-	0.2	0 2	0 3	0.2	0 2	0.2	0.2	-	0 3	0 2	0.2	0.4
Schistochila lehmanniana	L	-	-	-	0.5	0.8	0 3	-	0.7	0.7	0 5	0.2	0 3	0 8	0 8	0.7	1.0	1.0	0 6
Weymouthia mollis	M	-	-	-	0 3	0.5	0.3	-	0 3	0.2	0.3	0.2	0.2	-	1.0	0.7	0 4	0.4	0.4
Macromitrium microstomum	M	0 2	0.2	-	0 2	-	-	-	-	-	-	0 2	0.2	0.5	0 2	0 3	0.4	-	-
Plagiochila strombifolia	L	-	-	-	0.5	-	1.0	0 2	0.7	0.3	0.5	0.3	-	0.5	0.7	0.8	1.0	0.8	1.0
Camptochaete arbuscula	M	-	-	0 2	0.2	-	0.3	0.2	0 2	-	0.5	0 7	0.2	0 2	0.8	0.3	0.2	0.8	1.0
Cheilolejeunea mimosa	L	-	-	-	0.2	-	-	-	-	-	-	0.2	0.2	0 2	-	0 2	0.2	-	-
Tylimanthus pseudosaccatus	L	-	-	-	-	0 5	0.3	0.3	0 3	0 2	-	-	0.3	0.2	-	0 5	0.4	1.0	0.8
Cuspidatula monodon	L	0 2	0.5	-	0 3	0.2	0 2	0.3	0 2	0.3	0.5	-	-	1.0	1.0	0 7	1 0	0 2	0 6
Hypnodendron comosum	M	-	-	-	0.3	-	-	0.3	0 3	0.2	0.2	-	0.2	0.5	0.2	0.5	0.2	0.4	0.2
Frullania aterrima	L	-	0.2	-	-	-	-	-	-	0 2	0.2	-	-	0.3	-	0.5	-	-	-
Tylimanthus diversifolius Hodgs.	L	-	0.2	-	0.8	0.2	0.2	-	0 5	0 3	0 5	-	0.3	0 8	0 5	0 8	0 8	1.0	0 6
Lepidozia glaucophylla	L	-	0.2	-	0.2	-	-	-	0.5	0.5	0.3	-	-	0 7	0.3	0 8	0.6	0.2	-
Adelanthus falcatus	L	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	0 3	-	-	0.2
Kurzia tenax	L	-	-	-	-	-	-	-	0 3	-	-	-	-	0 2	-	0 2	0 2	-	-
Aneura alterniloba	L	-	-	-	-	-	-	-	0 2	0.2	-	-	-	0 2	-	0.3	-	-	-
Hymenophyton flabellatum	L	-	-	-	0.3	0 3	0.2	-	0.7	0 5	0.2	0 2	0 2	0.7	0.8	0 7	0.6	0.8	0 4
Leptophyllopsis laxus	L	-	-	-	-	-	-	-	0 2	0.3	-	-	0 2	0.2	-	0 5	0 2	-	-
Marsupidium surculosum	L	-	-	-	0.5	-	0 2	0 5	0.3	-	0 2	0.3	-	0.8	0 3	0.7	0.8	0 6	0.2
Trichocolea mollissima	L	-	-	-	0 7	0.2	-	0 2	0.5	0.7	0.3	0.2	0.3	0.8	1.0	1.0	0.6	0.4	1.0
Chandonanthus squarrosus	M	-	-	-	-	-	-	0.3	-	0 2	-	-	-	-	-	0 2	-	-	0 8
Acromastigum colensoanum	L	-	-	-	0.3	0.2	-	-	0 2	0.7	0 5	-	0 2	0.8	0 3	0.7	0.6	0 6	0 6
Lejeunea primordialis	L	-	-	-	-	-	-	-	-	-	-	0.3	0.2	0.2	0.5	0.2	-	-	-
Bazzania monilinervis	L	-	0.2	-	0.5	0.2	-	-	0.3	0 2	0.5	0.2	0.3	0.8	0.8	1 0	1.0	0.4	0 8
Distichophyllum crispulum	M	-	-	-	-	0.2	-	-	0.2	-	0.3	-	-	0.2	-	0 3	0.2	0 2	0 6
Tylimanthus tenellus	L	-	-	-	-	0.3	0 3	-	0.5	0.2	0 5	-	0.3	0 8	0.5	1.0	0.6	0.8	1.0
Schistochila pseudociliata	L	-	-	-	-	-	-	-	0 2	-	-	-	0.2	0.2	-	0 2	0.2	-	-
Telaranea centipes	L	-	-	-	-	-	0.2	0.2	0.2	-	-	-	-	0.2	-	0.5	0 4	0.2	-
Plagiochila spp.	L	-	0.2	-	0.3	0.2	-	-	0.2	0 3	0 2	-	-	0 8	1 0	0.8	0 8	-	-
Thamnobryum pumilum	M	-	-	-	-	-	-	-	-	0.2	0 3	-	-	0 2	0.2	0.5	-	-	0.4
Papillaria flavolimbata	M	-	0 2	-	0 3	-	-	-	-	0 2	-	-	-	0.3	1.0	0 2	0.6	-	-
Hypnodendron vitiense ssp *australe*	M	-	-	-	0 2	0.2	-	-	-	-	0.2	-	0 2	0.2	0.3	0 3	0 4	0.2	0.2
Jungermannia inundata	L	-	-	-	-	-	-	-	-	0.2	-	-	0 2	0.5	-	0 2	-	-	-
Brevianthus flavus	L	-	-	-	0.2	-	-	0 2	-	-	-	-	-	0.3	-	0.5	0.2	-	-
Lepicolea scolopendra	L	0 2	-	-	0 2	-	-	-	0 2	0.2	-	0 2	-	0 5	0.5	0.8	0.2	0.4	1 0
Plagiochila baileyana	L	-	-	-	0 2	-	-	-	0 2	0.3	-	-	-	0.3	0.5	0 8	0.4	0 4	-
Telaranea tetradactyla	L	-	-	-	-	-	-	-	-	0.2	0 2	-	-	0.3	0 5	0 2	0 2	-	-
Saccogynidium decurvum	L	-	-	-	-	-	-	-	0.2	-	-	-	0.3	0 2	-	0.5	0.2	0.6	0.6
Radula tasmanica	L	-	-	-	-	-	-	-	-	-	-	0.2	0 2	0 5	0.2	0.5	-	0.2	-
Acrochila biserialis	L	-	-	-	-	-	-	-	0 2	-	-	0 2	-	0 5	0 2	0.5	0.2	0 6	0.8
Acrobolbus cinerascens	L	-	-	-	-	-	-	-	-	-	-	0.2	-	0.5	0 2	0.3	0 6	0 2	-
Zoopsis setulosa	L	-	-	-	-	-	-	-	-	-	-	-	0.2	0 3	-	0 5	0.2	-	-

Age class		a	a	a	b	b	b	b	b	b	b	b	b	c	c	c	c	c	c
N² sites per age class group		6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	5	5	5
Adelanthus bisetulus	L	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	0.5	0.4	-	-
Paraschistochila tuloides	L	-	-	-	-	-	-	-	-	-	-	-	-	0.3	0.3	0.5	0 4	0 2	-
Plagiochila circinalis	L	-	-	-	-	-	-	-	-	-	-	-	-	0 2	0.2	0.5	-	-	0.4
Plagiochila radiculosa	L	-	-	-	-	-	-	-	-	-	-	-	-	0.2	0.2	0.3	0.2	0.2	0.2

Temporal distributions of bryophyte species in sites dominated by *E. regnans* or *E. obliqua* are shown in Tables 3.3 and 3.4 respectively. *Barbula calycina*, *Marchantia berteroana*, *Ceratodon purpureus* and *Funaria hygrometrica* are common to age class a for both *E. obliqua* and *E. regnans* forest.

Many species unique to *E. regnans* age class b forest occur only as singletons. More frequent exclusive species include *Chiloscyphus latifolius*, *Frullania probosciphora*, *Calyptopogon mnioides* and *Neckera pennata*. The latter three all occur epiphytically, with *C. mnioides* and *N. pennata* primarily occurring on *Pomaderris apetala* and *Acacia dealbata* (see Chapter 5). For *E. regnans* age class c forest, a mixture of mosses and liverworts such as *Chandonanthus squarrosus*, *Drepanolejeunea aucklandica* and *Hampeella alaris* are totally faithful. No species occurrence is significantly different between age classes. This is most likely due to the low numbers recorded.

Only *Racopilum cuspidigerum* var. *convolutaceum* is unique to age class b *E. obliqua* forest. The remaining few exclusive species in *E. obliqua* age class c forest are all liverworts; *Acrochila biseralis*, *Adelanthus bisetulus*, *Lejeunea primordialis*, *Paraschistochila tuloides* and *Teleranea tetradactyla*. Only *Plagiochila circinalis* and *P. radiculosa* are unique species that occur in both age class c *E. obliqua* and *E. regnans* forest. Some species in *E. obliqua* forest have occurrences which are significantly different between age classes, with occurrences higher in old growth than other age classes for example *Bazzania monilinervis*, *Chiloschyphus echinellus*, *Cuspidatula monodon*, *Plagiochila* spp., *P. stombifolia*, *Schistochila lehmanniana*, *Trichocolea mollisima* and *Fissidens pallidus*. Only the latter species is a moss.

Table 3.5 summarises the association of mean % cover of substrate and basal area of vascular species between age class groups. The mean % cover of above ground substrate types was not significantly different between forest age classes. Fallen branches and trees had similar mean % cover in both age class b and c. Roots and *Dicksonia antarctica* had significantly greater mean % cover in age class c than other age classes. Stumps had the greatest mean % cover and mean basal area in age class a. *Eucalyptus* spp., *Acacia dealbata* and *Pomaderris apetala* all had significantly greater mean basal area in age class b than remaining age class groups. Species with greater significant mean basal area in age class c than other age classes included *Anodopetalum*

biglandulosum and *Atherosperma moschatum*. Mean basal area of *Nothofagus cunninghamii* was significantly different between all age classes with the greatest value recorded for age class c. Total mean basal area was significantly different between all age classes and greatest for age class b.

Table 3.3. Presence/absence of selected species in sites dominated by Eucalyptus obliqua. *Species in less than 5 sites are excluded. Species are listed in order of their weighted average on the age variable. A dash indicates species is missing from site. a = age class a, b = age class b, c = age class c. Significance values from chi-square test. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, ns = not significant, 'n/a'indicates cells with expected counts less than 5 or 0.*

Species	a												b																								c																								p
Marchantia berteroana	1	1	1	1	-	1	1	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	n/a
Barbula calycina	1	1	1	1	1	1	1	-	1	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	n/a
Cephaloziella exiliflora	1	-	-	1	-	1	1	1	1	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	n/a
Ceratodon purpureus	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	n/a
Polytrichum juniperinum	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	n/a
Funaria hygrometrica	1	1	1	-	-	1	1	1	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	n/a
Cephaloziella hirta	-	-	-	-	-	-	1	1	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	n/a
Racopilum cuspidigerum (Schwagr.) Ångstr. var. *convolutaceum* (Mull.Hal.) Zant & Dijk.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	1	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	n/a
Campylopus introflexus	1	1	1	1	1	1	1	1	1	1	1	1	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	1	-	-	1	1	-	-	-	1	-	-	1	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	n/a
Rosulabryum billardieri var. *billardieri* (Schwägr) Spence	-	-	-	1	-	1	-	-	-	1	1	1	-	1	1	-	1	1	1	1	1	-	1	-	1	1	-	-	-	-	-	1	-	-	-	1	1	-	1	1	-	1	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	ns
Riccardia cochleata	-	-	-	-	1	-	-	1	-	1	-	1	1	-	-	1	-	1	1	1	1	-	1	-	1	1	1	1	-	-	1	1	-	-	-	-	-	-	-	-	-	1	1	1	1	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	ns
Chiloscyphus semiteres	-	-	-	1	1	1	-	1	1	1	-	1	1	-	1	1	1	1	1	1	1	-	1	1	-	-	1	-	-	-	-	-	1	1	1	1	1	-	1	-	1	1	-	-	1	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	ns
Kurzia hippurioides	-	-	-	-	-	-	-	1	-	-	1	1	-	-	-	-	-	-	1	1	1	1	1	-	1	1	1	1	1	1	1	1	-	-	-	-	-	-	-	-	-	1	1	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	ns
Riccardia crassa	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	1	1	1	1	-	1	-	1	1	1	1	-	-	1	1	-	-	1	-	-	-	-	1	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	ns
Atrichum androgynum	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	ns
Orthodontium lineare	-	-	-	-	1	-	-	1	-	-	-	1	1	1	1	1	-	-	1	1	1	-	-	-	1	-	1	1	-	1	-	-	1	-	-	-	-	-	-	-	1	-	1	1	-	1	1	-	1	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	ns
Kurzia compacta (Steph.) Grolle	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	1	1	1	1	-	1	-	-	1	1	1	1	-	1	1	-	-	-	-	-	-	-	1	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	ns
Ptychomnion aciculare	-	1	-	1	1	1	1	1	-	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	n/a
Lepidozia ulothrix	1	-	-	1	1	1	-	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	n/a
Temnoma townrowii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	1	-	-	ns
Dicranoloma billardieri	-	-	-	1	1	1	1	1	-	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	***
Rhaphidorrhynchium amoenum	-	1	-	1	1	-	1	-	-	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	***
Macromitrium archeri	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	1	1	1	-	1	1	1	-	1	1	1	1	-	1	1	1	-	-	-	1	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**
Dicranoloma dicarpum	-	-	-	1	-	1	-	-	-	-	-	-	1	1	-	1	1	-	1	1	1	1	-	-	1	1	1	1	-	1	-	1	-	-	1	-	-	-	-	1	1	1	1	-	-	1	1	-	1	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*
Isopterygium limatum	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	1	-	1	1	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	1	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	ns
Bazzania involuta	-	-	-	1	1	1	-	1	-	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	***
Pallaviciniaceae	-	-	-	-	-	-	-	-	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	1	-	-	-	1	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	ns
Dicranoloma robustum var. *setosum*	-	-	-	-	-	1	-	1	-	-	-	1	-	1	-	1	-	1	1	1	1	-	1	-	-	1	1	1	1	1	1	1	1	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	ns
Zygodon intermedius	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	1	1	1	-	-	-	-	-	-	1	-	1	-	-	-	-	1	-	-	1	-	-	-	-	-	1	-	-	1	-	-	1	1	1	-	-	-	1	ns

Species	a	b	c	p
Balantiopsis diplophylla	- - - - 1 - - - - - - -	1 1 1 - - 1 1 1 1 1 - 1 1 - 1 - - 1	- 1 - - 1 1 1 1 - - 1 - - - 1 1 1 1 1 - - -	**
Dicranoloma robustum	- - - - - - - 1 - - - -	- - 1 - - - 1 1 1 - 1 1 1 1 1 1 - 1	1 1 - 1 1 - - - - - - - - 1 - - 1 1 - 1 - 1	n/a
Leptotheca gaudichaudii	- - - 1 1 - 1 1 - 1 - 1	1 1 1 1 1 1 1 - 1 1 1 1 1 1 1 1 1 - 1	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	***
Gackstroemia weindorferi	- - - - 1 - - - - - - -	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 - 1 -	1 - - 1 - - 1 1 1 1 1 - 1 1 1 1 1 1 - 1 1 -	***
Cheilolejeunea mimosa	- - - - - - - - - - - -	1 - - - - - - - - - - - - - 1 1 - - -	1 - - - - - - - - - - - - - - - - - - 1 - -	ns
Distichophyllum pulchellum	- - - - - - - - - - - -	- - 1 - - - 1 1 - 1 1 - - 1 1 1 1 1	1 1 - - - - - - - - - - - - 1 1 1 1 - - - -	n/a
Dicranoloma menziesii	- - - 1 1 1 - 1 - - - 1	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 - 1 1	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	***
Lopidium concinnum	- - - - - - - - - - - - 1	- 1 - 1 - 1 - 1 1 1 1 1 - - 1 - - -	- 1 - - - 1 1 - 1 - - 1 - - 1 - - 1 1 1 - 1	n/a
Radula buccinifera	- - - - - - 1 - - - - - -	1 1 1 1 1 1 1 - 1 1 - 1 1 1 1 - - 1	- 1 - - - 1 1 1 1 - 1 1 - 1 1 1 - 1 1 1 1 1	***
Telaranea patentissima	- - - - - - 1 - 1 1 - - -	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	***
Heteroscyphus coalitus	- - - 1 - - - - 1 - - -	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 - 1	- 1 1 1 1 1 1 1 1 1 1 1 1 - 1 1 1 1 1 1 1 1	***
Heteroscyphus fissistipus	- - - 1 1 1 - - - - - -	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 - -	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	***
Zoopsis argentea	- - - - 1 - 1 1 - - 1 -	1 - - 1 1 1 - 1 1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1 1 - 1 1 1 1 1 1 1 1 1	***
Zoopsis leitgebiana	- - - - - - - - - - - -	- 1 1 - - 1 - 1 1 - 1 1 - 1 - - - -	- 1 1 1 - - - - - - 1 - - - 1 1 1 1 - - - 1	n/a
Hypnum cupressiforme	- - - - - 1 - 1 1 1 - -	- 1 - 1 1 - - 1 1 1 1 1 1 1 1 - 1 1	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 - - 1 1	**
Metzgeria decipiens	- - - - - 1 - - - - - -	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 -	1 1 1 1 1 1 1 - 1 1 1 1 - 1 1 1 1 1 1 1 - 1	***
Frullania clavata	- - - - - 1 - - - - - -	- 1 - 1 - 1 1 - 1 - - 1 1 1 1 - 1 1	1 - - - 1 1 - 1 1 1 1 - 1 1 - 1 - 1 - 1 - -	*
Rhizogonium novae-hollandiae	1 - - - - - - - - - 1 1	- 1 1 1 1 1 1 1 1 1 1 - 1 1 1 1 1 1	1 1 1 1 1 1 1 1 - 1 1 1 1 1 1 1 1 1 1 1 1 1	***
Leptostomum inclinans	- 1 - 1 1 1 - 1 - - - -	- - - - 1 - - - - - - - - - - 1 - -	- 1 - - 1 1 1 1 - - - 1 1 - - 1 1 1 - - 1 1	n/a
Frullania falciloba	- - - - - 1 - - - 1 - -	- 1 - - - - - 1 1 - - - - - - - - 1 -	1 - - - 1 1 - - 1 - 1 - 1 - - 1 - 1 - - - -	ns
Wijkia extenuata	- - - - 1 - - 1 - - - 1	1 1 1 1 1 1 1 1 1 - 1 - 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	***
Heteroscyphus conjugatus	- - - - - - - - - - - -	- 1 1 - - - - - 1 - 1 - - - - - - -	1 - - 1 - - 1 1 - - - - - 1 - - - - - - - -	ns
Chiloscyphus muricatus	- - - - 1 - - 1 - - - 1	- 1 - 1 - 1 - - 1 - - 1 - - 1 - - 1	- - 1 - 1 1 1 1 1 1 1 - - 1 1 - - 1 1 - -	ns
Wardburgiella leucocytus (Mull.Hal.) Tan, Schofield & Ramsay	- - - - - 1 - - - - - 1	1 1 1 - - 1 1 1 1 1 1 1 - 1 1 1 1 1	1 1 1 1 1 1 1 - 1 1 1 1 1 1 1 1 1 1 1 1 - 1	***
Lejeunea drummondii	- - - - - - - - - - - -	- 1 - 1 - 1 - 1 1 1 - 1 1 1 1 - - -	- 1 - 1 1 1 - - - 1 - 1 - 1 1 - - 1 1 1 1 -	**
Lepidozia laevifolia	1 - - - - - - 1 1 - - -	1 1 1 1 - - 1 1 1 1 1 - 1 - 1 1 - -	1 1 1 1 1 1 1 1 1 - 1 1 1 1 1 1 1 1 1 1 1 1	***
Hypnodendron spininervium ssp. *archeri*	- - - - - - - - - - - -	- - - - 1 - - 1 1 1 - - 1 1 1 1 1 -	1 1 - 1 1 - 1 1 - - 1 - - - 1 - 1 - - - - -	n/a
Symphyogyna podophylla	- - - - - - - - 1 - - -	1 1 1 - - 1 - 1 - 1 - 1 - - - - - -	- 1 - - 1 1 1 1 - 1 1 1 - - - 1 1 1 - - 1 -	n/a
Hypnum chrysogaster	- - - - 1 - - 1 1 - - -	- - 1 1 1 1 1 1 1 - 1 - 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	***
Riccardia spp.	- - - - - - - - - - - -	- - - - - - - - 1 - 1 - 1 - - - - -	1 - - - 1 - - - - 1 - - - - - 1 - - - - - -	ns
Kurzia hippuroides aff	- - - - - - - - - - - 1	1 - 1 1 - - - 1 1 1 1 1 1 1 1 1 1 1	1 1 1 1 - 1 1 1 1 1 1 1 - 1 1 1 1 1 - 1 - 1	***
Rhizogonium distichum	- - - 1 - - - - - - - -	1 1 1 1 - 1 - - - 1 - 1 - 1 1 - - 1	- 1 1 - 1 1 1 1 1 1 1 1 - - - 1 - - 1 1 1 1	**
Teleranea herzogii (Hodgs.) Hodgs.	- - - - - - - - 1 - - 1	- - 1 - - - - - - - - - - - - - - -	- - - - - - 1 1 1 1 1 - - - 1 - - - - - - -	ns
Telaranea mooreana	- - - - - - - - - - - -	- - 1 - - 1 - 1 - - 1 - - - - - - -	1 - - 1 - - 1 1 - - - - - 1 - - - - - - 1 -	ns

Species	a	b	c	p
Achrophyllum dentatum	- - - - - 1 - - - - - -	1 1 1 1 1 1 - - - 1 - 1 1 1 1 - - -	- 1 1 1 1 1 1 1 1 1 1 1 - - 1 1 1 - 1 1 1 1	***
Orthotrichum tasmanicum var *tasmanicum*	- - - - - - - - - - - - -	- - - - - - 1 - 1 - - - - - - - - -	- - - - - - - - - - 1 - - - - 1 1 - - - - -	ns
Plagiochila retrospectans	- - - - - - - - - - - - -	- - - - - - 1 - 1 - - - - - - - - -	- - - - - - - - - - - - - - - 1 1 1 - - - -	ns
Leucobryum candidum	- - - 1 - - - 1 - - - -	1 1 1 1 - 1 - - - 1 - 1 1 1 1 1 - 1	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 - - 1 1 1 1 1	**
Cyathophorum bulbosum	- - - - - - - - - - - - -	- 1 1 1 1 1 - - 1 1 - 1 1 1 1 - - -	- 1 1 1 - 1 1 1 1 - 1 1 1 - 1 1 - - 1 1 1 1	**
Mittenia plumula	- - - - - - - - - - - - -	1 1 - - - 1 - - - - 1 1 - - - - - -	- 1 - - 1 1 - 1 - - - - - - - 1 1 1 1 - - -	ns
Lepidozia procera	- - - - - - - - - - - - -	1 1 1 - 1 1 1 1 1 1 - 1 1 - 1 1 1 1	1 1 1 1 1 - 1 1 1 1 1 1 - 1 1 1 1 1 1 1 1 1	**
Chiloscyphus leucophyllus	- - - - - - - - - - - - -	1 - - - - - - 1 - 1 - - - - - - - -	1 - - 1 - - - - - - - - - - - - 1 - - 1 1 -	ns
Radula multiamentula	- - - - - - - - - - - - -	- - - - - - - - - - - - - 1 1 - - - -	- - - 1 - - - - - - - - - - 1 - - - 1 - - - -	ns
Podomitrium phyllanthus	- - - - - - - - - - - - -	- - 1 - - 1 - - 1 1 - 1 1 1 1 - - -	- 1 - 1 - 1 - 1 1 - - - - - 1 1 1 - 1 1 1 1	n/a
Riccardia aequicellularis	- - - - - - - - - 1 - - 1	1 - - - 1 - - - - - 1 - - - 1 - - -	- 1 1 - 1 - 1 1 1 1 - 1 - - 1 - - - - 1 - 1	ns
Plagiochila fasciculata	- - - - - - - - - - - - -	1 1 - 1 1 1 - - - 1 - 1 1 - 1 - 1 -	1 1 1 - - 1 - 1 1 1 1 1 1 - - 1 1 1 - - 1 1	***
Metzgeria saccata	- - - - - - - - - - - - -	- - - - - - - - 1 - 1 - - - - - - 1	1 - - - - - - - - - - - - 1 - 1 - 1 - - - -	n/a
Tylimanthus diversifolius Hodgs.	- - - 1 - - - - - - - -	1 1 - 1 1 1 1 - - - - - 1 - 1 - - -	- 1 1 1 1 1 1 - 1 1 - - - 1 1 1 1 1 1 1 - 1	***
Jamesoniella tasmanica	- - - - - - - - - - - - -	1 - - 1 - - - - - - - 1 - - 1 - - -	- 1 - 1 1 1 - - - - 1 - - - - 1 - - - - - -	ns
Cuspidatula monodon	- 1 - 1 1 1 - - - - - - -	- 1 - - 1 1 - - - - 1 1 - - - - - -	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 - 1 1 1 1 1 1 1	**
Macromitrium microstomum	- 1 - 1 - - - - - - - - -	- 1 - - - - - - - - - - - - - - - -	1 - 1 1 - - - - - - - 1 1 - - 1 - - - 1 - 1	ns
Fissidens tenellus	- - - - - - - - - - - - -	- - 1 - - 1 1 1 1 - - - - - - 1 - - -	- - - - 1 1 - 1 - 1 1 - 1 - - 1 - 1 - 1 - 1	n/a
Hypnodendron comosum	- - - - - - - - - - - - -	- - - 1 - - - 1 - 1 - - 1 - - - 1 -	1 1 - 1 - - 1 - - - - - - 1 - 1 1 1 - - - -	ns
Chiloscyphus echinellus	- - - - - - - - - - - - -	1 1 1 1 1 1 1 - - 1 - 1 - 1 1 - - 1	- 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	**
Frullania rostrata	- - - - - - - - - - - - -	- 1 - 1 - - - - - - 1 - 1 - 1 1 1 1	1 1 1 - 1 - - - 1 - - - - 1 1 1 1 1 - 1 - -	n/a
Heteroscyphus sinosus	- - - - - - - - - - - - -	- - - - - - 1 - - - 1 - - - - - - -	- - - - - - 1 1 - - - - - - - 1 1 - - - - -	ns
Heteroscyphus limosus	- - - - - - - - - - - - -	- 1 - - 1 1 - - - - - - - 1 - - 1 -	1 1 1 1 - 1 - - 1 - - - 1 1 - 1 - - - - - -	n/a
Glyphothecium sciuriodes	- - - - 1 - - - - - - - -	- - - - 1 - - - - - - - - - 1 1 - 1	- 1 - - - - - - - - - - - 1 1 - 1 1 - 1 1 1	ns
Radula compacta	- - - - - - - - - - - - -	- - - 1 - - - 1 1 - - - 1 1 - - 1 1	1 1 - 1 1 - 1 1 - - - - - 1 1 1 1 1 - 1 - -	n/a
Trichocolea mollissima	- - - - - - - - - - - - -	- 1 1 1 1 1 - - - 1 1 - - 1 1 - 1 -	- 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 - -	**
Schistochila pseudociliata	- - - - - - - - - - - - -	- - - - - - - - - 1 - - - - 1 - - -	- - - 1 - - - - - - - - - 1 - - - - 1 - - -	ns
Fissidens pallidus	- - - - - - - - - - - - -	1 1 1 - - 1 - - - 1 - 1 - - 1 - - 1	- 1 1 - - 1 1 1 1 1 1 1 1 - 1 1 1 - - - 1 1	**
Bazzania moniliinervis	- - - 1 - - - - - - - - -	1 1 - 1 - 1 - 1 - - - 1 - 1 1 - - -	1 1 1 1 - 1 1 1 1 1 - 1 1 1 1 1 1 1 1 1 1	**
Heteroscyphus billardieri	- - - - - - - - - - - - -	- 1 - - - 1 - - - - - - 1 1 - - - -	1 - 1 1 - - 1 1 - - - - 1 1 - - 1 1 - - - -	n/a
Hymenophyton flabellatum	- - - - - - - - - - - - -	- 1 - 1 - - - 1 - 1 - 1 - 1 1 - - -	- 1 1 - 1 1 1 1 - 1 1 1 - - 1 1 1 - 1 - 1 1	n/a
Schistochila lehmanniana	- - - - - - - - - - - - -	- - 1 1 - - - 1 - 1 - 1 1 1 1 - - -	- 1 1 1 1 1 1 1 - 1 1 1 - - 1 1 1 1 1 1 1 1	***
Goniobryum subbasilare	- - - - - - - - - - - - -	1 1 - - - - - - - - - - 1 - - - - -	- - 1 - - - - 1 1 - - - - - - 1 - - 1 1 1 1	n/a
Plagiochila strombifolia	- - - - - - - - - - - - -	- 1 - 1 1 - 1 1 1 - - - - - - - - -	1 1 - 1 - - 1 1 1 1 - - 1 - 1 1 1 1 1 1 1 1	**
Weymouthia cochlearifolia	- - - - - 1 - - - - - -	- - - - 1 - - - - - - - - - 1 - - -	- 1 - - - - - 1 1 1 - - 1 1 1 - - 1 - - - -	ns

Species	a	b	c	p
Leptophyllopsis laxus	- - - - - - - - - - - - -	- - - - - - - - - - 1 - - - - 1 - - -	1 - - - - - - - - - - - - - 1 1 - - 1 - -	ns
Lepicolea scolopendra	- 1 - - - - - - - - - - -	- - - 1 - - - - - - - 1 - - - - - - - -	1 1 - 1 - - - 1 1 - 1 - 1 1 - 1 1 1 - - - -	n/a
Acromastigum colensoanum	- - - - - - - - - - - - -	1 1 - - - - - - - - - 1 1 - - 1 - - -	1 1 - 1 1 1 1 1 - - - - - 1 1 1 1 1 1 1 - -	n/a
Frullania aterrima	- - - - - 1 - - - - - - -	- - - - - - - - - - - - - - - - - - - -	1 - - 1 - - - - - - - - - 1 - 1 1 - - - - -	ns
Papillaria flavolimbata	- - - - 1 - - - - - - - -	- 1 - - 1 - - - - - - - - - - - - - - -	- - 1 - 1 - 1 1 1 1 1 1 1 - - - - - - 1 1 1 -	n/a
Fissidens taylorii	- - - - - - - - - 1 - - -	- - - - - - - - - - - - - - - - - - - -	- - - - 1 - - - 1 - 1 1 1 - - - - - - - - -	ns
Plagiochila spp	- - - - - 1 - - - - - - -	- 1 - - 1 1 - - - 1 - - - - - - - - -	1 1 1 1 1 - 1 1 1 1 1 1 - 1 1 1 1 1 1 - 1 1	***
Dicranoloma platycaulon	- - - 1 - - - - - - - - -	1 - - - - - - - - - - - - - - - - - - -	1 1 - - 1 - - - 1 1 - - - - - 1 1 - - - 1 1	n/a
Marsupidium surculosum	- - - - - - - - - - - - -	- 1 - - 1 - - - 1 - - - - 1 - - - -	1 1 1 1 1 - - 1 - - 1 - - 1 1 - 1 1 1 1 1 -	n/a
Lembophyllum divulsum	- - - - - - - - - - - - -	- - - 1 1 - - - - - - - - - 1 - - -	- - - - - - 1 - 1 1 1 - 1 - - 1 1 - 1 - - - 1	n/a
Lepidozia glaucophylla	- - - - - 1 - - - - - - -	- 1 - - - - - - - 1 - - - - - - - - -	1 1 1 - - 1 1 - - - - 1 - 1 1 1 1 - 1 1 - 1	n/a
Plagiothecium lamprostachys (Hampe) Jaeg.	- - - - - - - - - - - - -	1 - - - - - 1 - - - - - - - - - - - -	- - 1 - - - - - - - - 1 1 - - - 1 - - 1 1 1 1	n/a
Radula tasmanica	- - - - - - - - - - - - -	- - - - - - - - - - - - - - - 1 1 - - -	1 1 - 1 - - - 1 - - - - - 1 - - 1 - - - - -	ns
Camptochaete arbuscula	- - - - - - - - - - - - -	- 1 - - - - - - - - - - 1 - - - - - -	- - - - - 1 1 1 1 1 1 - 1 - 1 - - - - 1 - -	n/a
Tylimanthus tenellus	- - - - - - - - - - - - -	- - - - - 1 - - - 1 - 1 - - 1 - - -	1 1 - 1 1 1 - 1 1 - - 1 1 1 1 1 1 1 - 1 1 -	n/a
Saccogynidium decurvum	- - - - - - - - - - - - -	- - - - - - - - - - - - - - - 1 1 - -	- 1 - - - - - - - - - - - - - 1 1 - 1 - 1 - - -	ns
Telaranea centipes	- - - - - - - - - - - - -	- - - - - - - - - - 1 - - - - - - - -	1 - - - - - - - - - - - - - 1 - 1 - 1 - 1 - -	ns
Plagiochila baileyana	- - - - - - - - - - - - -	- - - 1 - - - - - - 1 - - - - - - - -	- 1 - 1 - - - 1 - 1 - 1 - 1 1 1 1 - 1 1 - -	n/a
Brevianthus flavus	- - - - - - - - - - - - -	- - - 1 - - - - - - - - - - - - - - -	1 - - 1 - - - - - - - - - 1 1 - - 1 1 - - - -	n/a
Weymouthia mollis	- - - - - - - - - - - - -	- - - - 1 - - - - - - - - - 1 - - -	- - - - - - - 1 1 1 1 1 1 - - 1 1 1 1 - 1 - -	n/a
Jungermannia inundata	- - - - - - - - - - - - -	- - - - - - - - - - - - - - - 1 - - -	- 1 - 1 - 1 - - - - - - - - 1 - - - - - - - -	ns
Tylimanthus pseudosaccatus	- - - - - - - - - - - - -	- - - - - - - - - - - - - - - - - - - 1	- 1 - - - - - - - - - - - - - - 1 1 - - 1 1 -	ns
Acrobolbus cinerascens	- - - - - - - - - - - - -	- - - - - - - - - - - - - - - 1 - - - -	1 1 - 1 - - - - - - - 1 1 1 - - - 1 1 1 - -	n/a
Hypnodendron vitiense ssp. *australe*	- - - - - - - - - - - - -	- - - - - - - - - - - - - - - 1 - - -	- 1 - - - - 1 1 - - - - - - - 1 - - - 1 - 1 -	n/a
Zoopsis setulosa	- - - - - - - - - - - - -	- - - - - - - - - - - - - - - 1 - - -	- 1 - 1 - - - - - - - - - - 1 1 - 1 1 - - - -	n/a
Acrochila biserialis	- - - - - - - - - - - - -	- - - - - - - - - - - - - - - - - - - -	1 1 - 1 - - - 1 - - - - 1 1 - - 1 1 - - - -	n/a
Adelanthus bisetulus	- - - - - - - - - - - - -	- - - - - - - - - - - - - - - - - - - -	- - - - - - - 1 - - - - 1 1 - 1 - - - 1 1 -	n/a
Lejeunea primordialis	- - - - - - - - - - - - -	- - - - - - - - - - - - - - - - - - - -	1 - - - - - - - 1 - 1 1 - - - 1 - - - - - -	n/a
Paraschistochila tuloides	- - - - - - - - - - - - -	- - - - - - - - - - - - - - - - - - - -	- 1 - 1 - - 1 1 - - - - 1 1 - - 1 - 1 1 - -	n/a
Plagiochila circinalis	- - - - - - - - - - - - -	- - - - - - - - - - - - - - - - - - - -	1 - - - - - - 1 - - - - 1 1 - - 1 - - - - -	n/a
Plagiochila radiculosa	- - - - - - - - - - - - -	- - - - - - - - - - - - - - - - - - - -	- - - 1 - - 1 - - - - - - - - 1 1 1 - - - -	n/a
Telaranea tetradactyla	- - - - - - - - - - - - -	- - - - - - - - - - - - - - - - - - - -	- - 1 - - 1 - - 1 1 1 - - - - 1 - - - - - 1	n/a

Table 3.4. Presence/absence of all species in sites dominated by Eucalyptus regnans. *Species are listed in order of their weighted average on the age variable A dash indicates species is missing from segment. a = age class a, b = age class b, c = age class c.*

Species	a		b													c								
Barbula calycina	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cephaloziella hirta	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ceratodon purpureus	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Funaria hygrometrica	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Marchantia berteroana	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cephaloziella exiliflora	1	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polytrichum juniperinum	1	1	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pogonatum subulatum	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ditrichum difficile	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Riccardia wattsiana	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chiloscyphus subporosus	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepidozia concinna	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pyrrhobryum parramattense	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Racomitrium crispulum var. *tasmanicum*	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chiloscyphus bispinosus/C. lentus	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chiloscyphus multipennus aff.	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepidozia obtusiloba Steph.	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aneura alterniloba	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Heteroscyphus billardieri	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Jamesoniella tasmanica	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kurzia tenax	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plagiochila fuscella	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plagiochila incurvicolla	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Telaranea mooreana	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temnoma townrowii	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chiloscyphus minor (Nees) Engel & Schust.	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Species	a		b													c									
Chiloscyphus latifolius (L.) Engel & Schust.	-	-	-	1	1	1	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-
Sauloma tenella	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Sematophyllum subhumile var. *contiguum* (Mitt.) Tan, Schofield & Ramsay	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Fissidens taylorii	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Campylopus introflexus	1	1	-	1	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Frullania prohosciphora	-	-	-	1	1	1	-	-	-	1	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-
Fissidens pungens	-	-	-	-	1	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-
Calyptopogon mnioides	-	-	-	1	-	-	-	-	-	-	-	1	1	1	1	-	-	-	-	-	-	-	-	-	-
Lejeunea primordialis	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-
Macrocoma tenue ssp. *tenue*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Macromitrium microstomum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Neckera pennata	-	-	-	-	-	-	-	-	-	-	-	1	1	1	1	-	-	-	-	-	-	-	-	-	-
Rhynchostegium tenuifolium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Trachyloma planifolium	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-
Riccardia cochleata	-	-	1	-	1	1	1	-	1	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-
Chiloscyphus muricatus	-	-	1	1	-	-	-	1	-	1	1	-	1	-	-	1	-	-	-	-	-	-	-	-	-
Chiloscyphus villosus	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Riccardia spp.	-	-	-	1	1	1	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Orthotrichum tasmanicum var. *tasmanicum*	-	-	-	1	1	1	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-
Chiloscyphus semiteres	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	-	-	1	1	
Lejeunea drummondii	-	-	1	-	-	-	-	1	-	1	1	1	1	1	1	1	-	-	1	-	-	-	-	-	-
Chiloscyphus leucophyllus	-	-	1	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	
Racopilum cuspidigerum (Schwägr.) Ångstr. var. *convolutaceum* (Müll.Hal.) Zant. & Dijk.	-	-	1	-	1	-	-	1	-	-	-	1	1	1	1	1	-	-	1	-	-	-	-	-	-
Mittenia plumula	-	-	1	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Ulota lutea	-	-	-	1	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	
Orthodontium lineare	-	-	-	1	1	1	-	-	1	-	1	1	1	1	1	-	-	1	-	1	-	-	-	1	
Plagiothecium lamprostachys (Hampe) Jaeg.	-	-	1	-	1	-	1	1	1	1	1	1	1	1	1	1	-	-	1	1	-	-	-	1	

Species	a		b													c									
Riccardia crassa	-	-	1	-	1	-	-	1	1	-	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-
Goniobryum subbasilare	-	-	1	-	-	-	-	1	1	-	1	-	1	-	-	-	-	-	-	1	-	1	-	-
Rhizogonium distichum	-	-	1	-	1	-	-	1	1	1	1	1	1	1	1	1	-	-	-	1	1	1	-	-
Thuidium furfurosum	-	-	1	1	-	-	-	1	-	1	-	1	1	-	1	1	1	-	1	-	-	-	-	-
Acrocladium chlamydophyllum	-	-	-	1	1	1	-	-	-	-	-	1	1	1	1	1	1	-	1	-	-	-	-	-
Geocalyx caledonicus	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Heteroscyphus sinosus	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Kurzia compacta (Steph.) Grolle	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Heteroscyphus coalitus	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-	1	1
Ulota viridis	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Campylopus flindersii	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-
Lepidozia glaucophylla	-	-	-	-	-	-	-	1	1	1	1	-	-	-	-	1	-	-	1	-	-	-	-	-
Fissidens tenellus	-	-	1	-	-	-	-	1	1	1	1	1	1	-	1	-	-	1	1	1	-	-	-	1
Dicranoloma robustum	-	-	1	1	1	1	1	1	1	1	1	-	-	-	-	-	1	-	-	1	1	1	-	1
Heteroscyphus fissistipus	-	-	1	-	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-	1	1
Kurzia hippurioides aff.	-	-	1	-	1	-	1	1	1	1	-	-	1	-	-	1	-	-	1	1	-	1	-	-
Dicranoloma dicarpum	-	-	-	1	1	1	1	-	-	1	1	1	-	1	1	-	1	1	1	-	-	1	-	1
Achrophyllum dentatum	-	-	1	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	-	-	1	-	-
Weymouthia cochlearifolia	-	-	1	-	-	-	-	1	1	1	1	1	1	1	1	1	-	-	1	-	1	1	1	-
Dicranoloma robustum var. *setosum*	-	-	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	1	1	-	-	1	1	1
Ptychomnion aciculare	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Frullania falciloba	-	-	-	1	1	1	-	1	-	1	1	1	1	1	1	1	-	1	1	-	1	1	1	-
Rosulabryum billardieri var. *billardieri* (Schwägr.) Spence	-	-	1	1	1	1	-	1	-	-	-	1	-	1	1	-	1	1	1	1	-	-	-	1
Warburgiella leucocytus (Müll. Hall.) Tan, Schofield & Ramsay	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1
Zygodon intermedius	-	-	1	1	-	1	-	1	1	-	-	-	1	1	1	1	-	-	1	1	1	-	1	-
Distichophyllum microcarpum	-	-	1	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	1	-	-	1	-	-
Cyathophorum bulbosum	-	-	1	-	-	1	-	1	1	1	1	1	1	1	-	1	1	1	1	1	-	1	-	-
Macromitrium archeri	-	-	1	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	1	-	-	-	-	-

Species	a		b													c									
Frullania clavata	-	-	1	-	-	-	-	1	1	1	1	1	1	1	1	1	1	-	1	-	-	1	1	1
Plagiochila retrospectans	-	-	-	1	-	-	-	-	-	-	-	-	-	1	1	-	-	-	1	-	-	-	1	-
Bazzania involuta	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lepidozia ulothrix	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rhizogonium novae-hollandiae	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Wijkia extenuata	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Zoopsis argentea	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rhapidorrhynchium amoenum	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Leptotheca gaudichaudii	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lembophyllum divulsum	-	-	-	1	1	1	-	1	-	-	-	1	1	-	1	1	-	1	1	-	-	1	-	1
Hypnum chrysogaster	-	-	1	1	1	1	1	-	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	-
Heteroscyphus limosus	-	-	-	1	1	1	-	-	-	-	-	1	-	-	-	-	1	-	-	-	1	-	1	-
Lepidozia laevifolia	-	-	-	1	1	1	-	1	1	-	1	1	-	1	-	1	1	1	1	-	1	-	1	-
Telaranea patentissima	-	-	1	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1
Podomitrium phyllanthus	-	-	1	-	-	-	-	1	1	1	1	-	-	-	-	1	-	-	1	1	-	1	-	-
Weymouthia mollis	-	-	1	-	-	-	-	1	1	1	1	-	-	-	-	1	-	1	-	1	-	1	-	-
Thuidium sparsum	-	-	1	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	-	-	1	1	1
Dicranoloma menziesii	-	-	1	1	1	1	1	1	1	1	1	-	-	1	1	1	1	1	1	1	1	1	1	1
Kurzia hippurioides	-	-	1	1	1	1	1	1	1	-	-	-	-	-	-	1	-	-	-	1	1	1	1	1
Hypnum cupressiforme	-	-	1	1	-	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Radula buccinifera	-	-	1	-	-	-	-	1	1	1	1	-	-	1	1	1	1	1	1	-	-	-	1	1
Dicranoloma billardieri	-	-	1	1	-	-	1	1	1	-	-	1	-	1	1	1	1	1	1	-	1	-	1	1
Lopidium concinnum	-	-	1	-	-	-	-	1	1	-	-	1	1	1	1	1	1	1	1	1	-	-	-	1
Camptochaete arbuscula	-	-	-	-	1	1	-	-	1	1	1	1	1	-	1	-	1	-	1	1	1	1	1	1
Metzgeria decipiens	-	-	1	-	-	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ditrichum cylindricarpum	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Hypnodendron comosum	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-
Campylopus pyriformis var. a	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-

Species	a		b													c									
Marsupidium surculosum	-	-	1	-	-	1	1	-	1	-	-	-	-	-	-	1	1	1	-	-	1	-	-	-
Lepidozia procera	-	-	-	1	1	1	1	-	1	-	-	-	-	-	-	-	-	-	1	1	1	1	1	-
Campylopus pyriformis	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Isopterygium limatum	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Pallaviciniaceae	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Gackstroemia weindorferi	-	-	-	1	1	1	1	1	1	1	-	1	-	-	-	1	1	1	1	-	1	1	1	1
Campylopus purpureocaulis Dusén	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	1
Plagiochila fasciculata	-	-	1	-	-	-	-	1	1	1	-	-	1	1	-	1	-	-	1	1	-	1	1	1
Chiloscyphus echinellus	-	-	-	1	-	-	-	1	1	1	-	-	1	-	1	1	-	-	1	1	1	1	1	-
Fissidens pallidus	-	-	-	-	-	-	-	1	-	1	1	1	1	-	-	-	1	1	-	-	1	1	1	-
Chiloscyphus novaezeelandiae	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Campylopus bicolor var. *ericeticola*	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	1	-	1	-	-
Radula ratkowskiana	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-
Camptochaete deflexa	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1
Leucobryum candidum	-	-	1	-	-	1	1	-	-	1	-	-	-	-	-	-	-	1	-	1	1	-	1	1
Distichophyllum pulchellum	-	-	1	-	-	-	-	1	1	1	-	-	-	-	-	1	1	-	1	1	-	1	-	-
Plagiochila strombifolia	-	-	-	1	1	1	-	-	1	1	-	1	1	-	-	1	1	1	1	1	1	1	1	1
Frullania rostrata	-	-	-	1	-	-	1	1	1	1	1	-	-	-	-	1	-	1	1	1	1	1	1	1
Radula compacta	-	-	-	-	-	-	-	-	1	1	-	-	-	1	-	-	-	-	1	1	1	-	-	1
Tylimanthus diversifolius Hodgs.	-	-	1	-	-	-	-	1	1	1	-	-	-	1	-	1	1	1	1	-	1	-	1	1
Zoopsis leitgebiana	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	1	-	1	-	-	-	1	-	-
Hypnodendron vitiense ssp. *australe*	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	1	1	-	-	-	-	-	1	-
Thamnobryum pumilum	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	1	-	-	-	-	-	1	1	-
Glyphothecium sciuriodes	-	-	1	-	-	-	-	1	1	1	-	-	-	-	1	1	1	-	1	1	1	1	1	1
Bazzania monilinervis	-	-	-	-	-	-	-	-	1	1	-	-	-	-	1	1	-	-	-	1	1	1	1	-
Schistochila lehmanniana	-	-	1	-	-	-	-	1	1	-	-	-	-	1	-	1	1	1	1	1	-	1	1	-
Metzgeria spp.	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
Trichocolea mollissima	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	1	-	-	-	1	1	1	1	1

Species	a		b													c									
Symphyogyna podophylla	-	-	-	-	-	-	-	1	1	-	-	-	-	-	1	1	1	1	1	1	-	1	-	-
Acromastigum colensoanum	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	1	-	-	1	1	-	1
Distichophyllum crispulum	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	1	-	-	-	1	-	1	1	-
Tylimanthus tenellus	-	-	-	-	-	-	-	1	1	-	1	-	-	1	-	1	-	1	1	1	1	1	1	1
Atrichum androgynum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	1	-	-	-	-	-
Leptostomum inclinans	-	-	-	1	1	1	-	-	-	-	1	-	-	-	-	1	1	1	1	1	1	1	1	1
Balantiopsis diplophylla	-	-	1	-	-	-	-	1	1	-	-	-	-	-	-	1	1	1	1	1	1	-	1	-
Hymenophyton flabellatum	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	1	1	-	1	1	1	-	-	-
Hypnodendron spininervium ssp. *archeri*	-	-	-	-	-	-	1	-	1	-	-	-	-	1	-	1	1	1	1	1	1	-	1	1
Tylimanthus pseudosaccatus	-	-	-	-	-	-	-	1	1	-	-	-	-	1	-	1	1	1	1	1	1	1	1	-
Cuspidatula monodon	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	1	-	1	-
Riccardia aequicellularis	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	1	-	1	-	-	-	-
Acrochila biserialis	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	1	1	1	1	1	1	-
Metzgeria saccata	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	1	1	-	-	-
Catagonium nitens (Brid.) Cardot ssp. *nitens*	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	1	-
Saccogynidium decurvum	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	1	1	1	-	-
Lepicolea scolopendra	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	1	1	1	1	1	1
Adelanthus falcatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Chandonanthus squarrosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	1	-
Cheilolejeunea mimosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Daltonia splachnoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Diplasiolejeunea plicatiloba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Drepanolejeunea aucklandica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	1	-
Calyptrochaeta brownii (Dix.) J.K. Bartlett	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-
Hampeella alaris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-
Heteroscyphus knightii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Hypopterygium didictyon Müll. Hal.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-
Leptophyllopsis laxus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-

Species	a		b													c									
Plagiochila baileyana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-
Plagiochila circinalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-
Plagiochila radiculosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-
Pyrrhobryum mnioides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Radula tasmanica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Sphagnum australe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Telaranea centipes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Teleranea herzogii (Hodgs.) Hodgs.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Brachythecium salebrosum/ rutabulum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Radula spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Hypnodendron spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Plagiochila spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-

*Table 3.5. Mean cover of substrate types and basal area of vascular species for forest age classes. Tukeys test was used to denote different means at the 95% confidence interval, indicated by differing superscripts. Number of sites (n) in age class:age classes: a = 1 – 18 years, n = 18; b = 31 – 67 yrs, n = 54; c = > 110 years, n = 33. *p < 0.05, **p < 0.01, ***p < 0.001, ns = not significant.*

Variable	Age class a	Age class b	Age class c	p
% Cover of substrates				
Log	12.66^{A}	11.53^{A}	9.28^{A}	0.056 ns
Fallen branch	0.72^{A}	1.29^{B}	1.63^{B}	0.000***
Tree	0.78^{A}	4.21^{B}	4.58^{B}	0.000***
Root	0.01^{A}	0.19^{A}	0.75^{B}	0.000***
Dead tree	0.29^{A}	0.99^{A}	0.43^{A}	0.086 ns
Stump	4.59^{A}	1.22^{B}	0.57^{B}	0.000***
Upturned tree base	0.63^{A}	0.83^{A}	0.57^{A}	0.680 ns
Rock	1.67^{A}	1.81^{A}	0.42^{A}	0.100 ns
Dicksonia antarctica (alive/vertical)	0.12^{A}	0.27^{A}	0.97^{B}	0.000 ns
Dicksonia antarctica (dead/horizontal)	0.35^{A}	0.30^{A}	0.51^{A}	0.634 ns
Total cover	21.83^{A}	22.63^{A}	19.71^{A}	0.210 ns
Basal area of vascular species				
Dead trees	1.85^{A}	2.00^{A}	0.81^{A}	0.265 ns
Stumps	1.59^{A}	0.17^{B}	0.00^{B}	0.011*
Acacia dealbata	0.44^{B}	1.42^{A}	0.04^{B}	0.016*
Acacia melanoxylon	0.19^{A}	0.67^{A}	0.25^{A}	0.231 ns
Acacia riceana	-0.00^{A}	0.12^{A}	-0.00^{A}	0.394 ns
Acacia verticillata	0.00^{A}	0.03^{A}	0.00^{A}	0.628 ns
Anodopetalum biglandulosum	0.00^{A}	0.00^{A}	1.52^{B}	0.004**
Anopterus glandulosus	0.00^{A}	0.03^{A}	0.22^{A}	0.126 ns
Atherosperma moschatum	0.08^{A}	2.00^{A}	8.17^{B}	0.000***
Banksia marginata	-0.00^{A}	0.01^{A}	0.00^{A}	0.628 ns
Cassinia acueleata	0.08^{A}	0.00^{B}	0.00^{B}	0.007**
Cenerrhenes nitida	0.00^{A}	0.00^{A}	0.04^{A}	0.339 ns
Coprosma quadrifida	0.00^{A}	0.00^{A}	0.02^{A}	0.339 ns
Cyathodes glauca	0.00^{A}	0.12^{A}	0.00^{A}	0.628 ns
Dicksonia antarctica	0.89^{A}	5.75^{A}	13.32^{B}	0.000***
Eucalyptus brookeriana	0.00^{A}	0.61^{A}	0.00^{A}	0.073 ns
Eucalyptus delegatensis	1.18^{A}	5.22^{B}	0.04^{A}	0.024*
Eucalyptus obliqua	4.93^{A}	12.06^{B}	5.52^{A}	0.024*
Eucalyptus regnans	1.96^{A}	8.43^{B}	2.75^{A}	0.006**
Eucryphia lucida	0.00^{A}	0.74^{A}	2.02^{A}	0.076 ns
Leptospermum scoparium	-0.00^{A}	0.18^{A}	-0.00^{A}	0.628 ns
Leptospermum spp.	0.00^{A}	0.27^{A}	0.04^{A}	0.683 ns
Lomatia ilicifolia	0.00^{A}	0.00^{A}	0.02^{A}	0.339 ns
Monotoca glauca	0.00^{A}	0.25^{A}	-0.00^{A}	0.213 ns
Nematolepis squamea ssp. *squamea*	-0.00^{A}	1.80^{B}	0.20^{A}	0.040*
Nothofagus cunninghamii	0.12^{A}	4.80^{B}	10.54^{C}	0.000***
Olearia argophylla	0.04^{A}	1.80^{A}	1.78^{A}	0.391 ns
Phyllocladus asplenifolius	0.07^{A}	0.21^{A}	0.24^{A}	0.725 ns
Pittosporum bicolor	0.00^{A}	0.25^{A}	0.06^{A}	0.315 ns
Pomaderris apetala	1.18^{A}	12.59^{B}	0.06^{A}	0.000***
Prostanthera lasianthos	0.00^{A}	0.06^{A}	-0.00^{A}	0.503 ns
Tasmannia lanceolata	0.00^{A}	0.03^{A}	0.02^{A}	0.823 ns
Total basal area	14.56^{A}	61.53^{B}	47.07^{C}	0.000***
Basal area of rainforest species	1.18^{A}	15.85^{B}	37.95^{C}	0.000***
Basal area of *Eucalyptus* spp.	8.07^{A}	26.32^{B}	8.30^{A}	0.000***

Discussion

Not surprisingly, the species which occurred most frequently in age class a (1 – 18 years) such as the liverworts *Marchantia berteroana and Cephaloziella exiliflora*, and the 'fire mosses', *Barbula calycina, Ceratodon purpureus, Funaria hygrometrica,* and *Polytrichum juniperinum,* have been recorded as dominating early regeneration of mixed forest previously (Cremer and Mount 1965; Duncan and Dalton 1982; Hill and Read 1984). The moss spores and propagules are easily dispersed by the wind and also cover the ground of boreal forests (Heinselman 1981). Duncan and Dalton (1982) described the early successional sequence of these species after fire in mixed forest. Whereas these species are noteworthy colonisers of the soil, *C. exiliflora* exists predominantly on burnt wood (Scott 1985). Duncan and Dalton (1982) found that burnt substrates did not inhibit germination of non-colonising species. However, establishment and persistence may have been affected by the early colonising species that are faster growers than non-colonising species. The present study found these early colonising species did not strongly persist into older forest. Occasional occurrence of some of these species in older forest is probably due to localised disturbances such as falling trees or mammal and bird scratching. Tree fall has been found to maintain high bryophyte diversity in boreal forests (Jonsson and Esseen 1990).

The conversion of forests aged 1 – 18 years to forests aged 31 – 67 years (age class b) includes extensive canopy development, an increase in the amount of particular substrates and an increase in the diversity and frequency of bryophytes. This may be perceived as a successional change. Many species such as *Plagiochila fasciculata* and *Heteroscyphus billardieri* spanned a broad temporal distribution from forest aged 31 – 67 to older forest (> 110 years). Therefore these species did not show a strong association with a particular successional stage. Similar results were found between different age classes of forest in the Pacific northwest of North America (Halpern and Spies 1995). Similarities in microhabitat environment and coverage of substrates may explain species occurrences across successional stages.

The majority of bryophyte species found in wet eucalypt forest of the present study are secondary or climax species. Once the vascular species have recovered from disturbance these bryophyte species re-establish in restored microhabitats. Epiphytic

bryophyte species develop in the 31 – 67 year (age class b) successional stage. For example, the mosses *Neckera pennata* and *Calyptopogon mnioides* are strongly associated with tree species *Pomaderris apetala* and *Acacia dealbata* (see Chapter 5). Vital attributes of the tree species may influence the association with the moss species. After a fire disturbance in old growth mixed forest, both species regenerate from stored or dispersed seed (Ashton 1981b): *P. apetala* stores seed in the soil for < 100 years (Cunningham and Cremer 1965) whereas *A. dealbata* stores seed for 300 – 400 years (Gilbert 1959). *A. dealbata* becomes decadent after ~ 70 years (Gilbert 1959) and *P. apetala* < 100 years (Ashton 1981b). In the present study, *P. apetala* and *A. dealbata* had their greatest mean basal area in age class b. If no further disturbance occurs within the lifetime of these two tree species, they are replaced by rainforest species (see Figure 2c in Ashton 1981b). If disturbance does occur then *C. mnioides* and *N. pennata* will most likely persist where *P. apetala and A. dealbata* occur. This is demonstrated where *C. mnioides* has been recorded from wet eucalypt forests under recurrent disturbance elsewhere (Jarman and Kantvilas 1994; Turner 1996; Jarman and Kantvilas 2001a).

After 110 years, if a disturbance, such as fire, does not terminate the succession eucalypts become dominant over a shady understorey of rainforest species, with a later potential to become cool temperate rainforest. These older forests have a greater basal area of rainforest species than younger forests. Although other substrates, such as logs, have similar coverage in age class b and c forest, decay is more advanced in older forest (Lindenmayer *et al.* 1999). Liverworts dominate in this shady, moist environment. The present study found more exclusive liverworts in age class c (> 110 years) than other age classes. Bryophytes, in particular liverworts, thrive in moist environments (Söderström 1981; Gradstein *et al.* 1989). Other studies have found greater numbers of liverworts in moist environments than mosses (La Roi and Stringer 1976; Gradstein *et al.* 1989; Pharo and Beattie 1997). In particular, the leafy liverworts, *Adelanthus bisetulus*, *Paraschistochila tuloides*, *Plagiochila circinalis* and *P. radiculosa* were found only in older aged forest. Jarman and Kantvilas (2001a) also did not record these species from wet eucalypt forest (~ age class b forest in the present study). Spore and vegetative dispersal by bryophytes is restricted to moist environments (Crum 2001). Although long-range wind dispersal is achievable, it is not common (van Zanten and Pócz 1981) and is possibly ineffectual when associated with windbreak forest habitats (Crum 2001). The movement of liverwort species into older forest is more likely to

have occurred with the establishment of associated vascular plants and a moist environment. Further research regarding the regeneration strategies of liverwort species in wet eucalypt forests is needed.

P. radiculosa was found to be associated with rainforest species in older forest (> 110 years) in the present study (Chapter 5). Rainforest species, such as *Nothofagus cunninghamii* and *Atherosperma moschatum*, only reach maturity after 30 years and assert dominance in mixed forest after species such as *P. apetala* and *A. dealbata* expire (Noble and Slatyer 1980). As mixed forest changes into cool temperate rainforest, this dominance then continues. The presence of *P. radiculosa* in old growth mixed forest is probably a factor of the microclimate and the availability of suitable habitats like these rainforest vascular species. These factors may also explain the presence of *P. radiculosa* in stands of cool temperate rainforest (Jarman and Kantvilas 1994; Jarman and Kantvilas 1995b). Crum (2001, p 29) states 'It is certain that bryophytes growing in the shelter of higher plants migrate gradually with those same plants as they respond to changes in the environment'. Many species of both bryophyte and lichen have been found to be dependent on old trees and old forests elsewhere than Australia (Söderström 1988a; Lesica *et al.* 1991).

Many different vascular plant communities are found in wet eucalypt forests dominated by *E. obliqua* or *E. regnans* (Kirkpatrick *et al.* 1988). *E. regnans* is found on sites of greater fertility and occasionally at higher altitude than *E. obliqua* (Kirkpatrick *et al.* 1988), thus different understorey assemblages and conditions occur. Fire affects also differ; *E. obliqua* has a thick bark that renders it more resistant to fires than the fibrous/gum bark of *E. regnans* (Ashton 1981a). There were fewer *E. regnans* dominated forest sites sampled than *E. obliqua*. Although this may have influenced the number of faithful species, there were a number of species that were faithful in both age class forest types. *Racopilum cuspidigerum* var. *convolutaceum* was unique to age class b *E. obliqua* forest. It is a widespread species in Tasmania (Moscal and Kirkpatrick 1997) and has been found previously in regenerating wet eucalypt forest of similar age dominated by *E. delegatensis* (Kantvilas and Jarman 1993). Within forest aged 31 - 67 years it does not seem restricted to a particular substrate and may instead be associated with environmental factors not studied here (see Chapter 5; Scott *et al.* 1976). *Frullania probosciphora*, *Calyptopogon mnioides* and *Neckera pennata* in *E. regnans* age class b forest all occur epiphytically, with *C. mnioides* and *N. pennata*

primarily occurring on *Pomaderris apetala* and *Acacia dealbata* (see Chapter 5). Little is known of the dispersal and reproductive strategies and capacities of these species.

Bryophytes, like their vascular plant counterparts, follow a successional sequence in wet eucalypt forest. The present study also found that bryophytes follow a temporal sequence in both *E. regnans* and *E. obliqua* dominated forests. The occurrence of some bryophytes species appears to be closely related to the co-occurrence of particular vascular plant species. Therefore, the survival and existence of these bryophytes is partly dependant on temporal and spatial persistence of vascular species.

Chapter Four

Relationships between bryophyte and vascular plant species richness and composition in mixed forest, Tasmania

Abstract

In conservation and management of wet eucalypt forest diversity, vascular plants are assumed to be surrogates for more cryptic taxa such as bryophytes. Vascular plant and bryophyte species were recorded from 105 sites, in three age class groups: a (1 – 18 years since disturbance), b (31 – 67 years) and c (> 110 years). These data were used to investigate to what degree vascular species richness and composition can be used as surrogates for bryophyte species richness and composition and whether reserves selected on the basis of representing vascular plants capture bryophyte diversity. Vascular plant species richness and fern species richness were significant but poor predictors of bryophyte species richness. The richness of ferns (in particular epiphytic ferns) was not a significant predictor of bryophyte species richness in old growth forest sites alone. A weak significant correlation was found between vascular plant species composition and bryophyte species composition. For age class groups, the stongest relationship was between the species compositions of all vascular plants and bryophytes in age class c. A minimum reserve set of 31 sites was selected to reserve all vascular species at least once. A large percentage (82.9%) of bryophyte species also reserved at least once in this selection. Reserving all vascular plants twice required a minimum reserve set of 41 sites and reserved an additional ten bryophyte species that were unreserved in the 31- subset of sites, bringing reservation of bryophytes up to 87.5%. These results indicate that reserves selected using vascular plants do reserve a large number of bryophyte species. For all reserve sets, more sites of regenerating forest (age class b) were required than old growth forest (age class c). Whereas old growth forest sites contributed substantially to reserve sets, the higher incidence of regenerating sites highlights the importance of conservation of the seral stages of wet eucalypt forest.

Introduction

Mixed forest is defined as vegetation with a rainforest understorey and eucalypt overstorey (Gilbert 1959). Fires maintain mixed forest at intervals of 100 - 350 years (Gilbert 1959; Jackson 1968; Mount 1979; Hickey 1994). The older stands of mixed forest are termed 'old growth forest' and have great aesthetic and natural significance. However, if there is an absence of fire for more than approximately 400 years, the eucalypts of old growth forests die out, leaving rainforest (Jackson, 1968). The term 'wet eucalypt forest' includes both mixed forest and forests with broad-leaved shrubs and/or ferns dominant in the understorey (Kirkpatrick *et al.* 1988).

Bryophytes (mosses and liverworts) contribute more to the species level of biodiversity in wet eucalypt forests than vascular plants (Ashton 1986; Jarman and Kantvilas 1994; Jarman and Kantvilas 1995b; Jarman and Kantvilas 1997; Pharo and Beattie 1997; Pharo *et al.* 1999). Unlike most vascular plants, bryophytes are difficult to identify to species level. They are not routinely included in vegetation surveys of wet eucalypt forest. Conservation and management of these forests is largely based on vascular plants, which are assumed to act as a surrogate for all other components of biodiversity (Kirkpatrick *et al.* 1988; Jarman *et al.* 1991; Woodgate *et al.* 1994; Commonwealth of Australia and the State of Tasmania 1996).

Research that investigates the relationships between bryophytes and vascular plants in the wet eucalypt forests of Australia is scarce. Jarman and Kantvilas (1994) compared the bryophytes, lichens and vascular plants sampled from two sites in eucalypt forest and one in rainforest, finding that clustering of sites was similar when using vascular or non-vascular species composition. Jarman and Kantvilas (1995b), in a study of fifteen Tasmanian rainforest communities, at the suballiance level (five sites in each), found that bryophytes formed recognisable communities, providing support for the rainforest classification based on vascular plants. Fensham and Streimann (1997) found that moss species richness of dry rainforest in north Queensland was strongly correlated with vascular plant species richness. In dry eucalypt forest of New South Wales, Pharo *et al.* (1999) found fern species richness to be significantly correlated with bryophyte species richness and that wet eucalypt forest sites clustered well when defined by either vascular plant, bryophyte or lichen species composition. Elsewhere, Ingerpuu *et al.* (2001) in a study of Estonian moist forests and mires found a positive correlation

between species richness of bryophytes and vascular plants in all community types. They also found regional species pools for bryophyte and vascular plants were significantly correlated. Glaser *et al.* (1990) found a close relationship between the number of vascular species and bryophyte species per community. They also found that communities were well defined by vascular plant or bryophyte species composition data or a combined data set. In forested slopes of central Sweden, no correlation between bryophyte and vascular species richness was found (Söderström 1981). Congruence in richness or composition between groups of taxa may be a useful management tool in the sense that 'indicator' groups of taxa could be used as surrogates for biodiversity where resources and expertise are limited.

This study is the first of its kind to investigate relationships between bryophytes and vascular plants in old growth and regenerating wet eucalypt forest. The following questions are addressed: (1) Are the species richness of mosses, liverworts and bryophytes as a group, significantly related to the species richness of trees, tall shrubs, short shrubs, non-woody angiosperms, ferns, ground ferns, epiphytic ferns and all vascular plants? (2) To what degree can vascular species composition be used as a surrogate for bryophyte species composition? (3) Does predictability differ between old growth forest and earlier stages in succession after fire?

Materials and Methods

Study area

Data were collected from 105 sites (Figure 3.1), including 69 sites that were sampled earlier by Hickey and Savva (1992) in a vascular plant study. Details for the 105 sites regarding methods of site selection, site locations, disturbance history and dominant *Eucalyptus* species are given in Chapter 3. Mean annual temperature ranges from 6.1 to 12.1 °C (mean 9.86 ± 0.15 °C) and mean annual rainfall ranges from 1104 to 2104 mm (mean 1471.21 ± 18.31 mm).

Vegetation sampling

For details of vegetation sampling refer to Chapter 2. Nomenclature follows Dalton *et al.* (1991) for mosses, Ratkowsky (1987) for liverworts and Buchanan (1999) for vascular plants except where authorities are given.

Analysis

Species richness

Species presence/absence, for both vascular plants and bryophytes, was entered into the data package DECODA (Minchin 1990). Lifeform was included as a variable for vascular species and applied to the predominant habit of the mature plant. Species were assigned to one of the following eight groups: tree (greater than 5 m tall, single stemmed), tall shrub (greater than 8 m tall, multi-stemmed), short shrub (less than 2 m tall, multi stemmed from base, woody species), non-woody angiosperm, all ferns, ground fern and epiphytic fern. Bryophytes were classed as moss or liverwort. Sites were divided into age classes since disturbance: a = 1 – 18 years, b = 31 - 67 years, c = > 110 years.

Species richness was calculated as the number of species at a site in each class. Simple and multiple regression was used to investigate relationships between species richness of moss, liverwort and all bryophytes and species richness of trees, tall shrubs, short shrubs, non-woody angiosperms, ferns, ground ferns, epiphytic ferns and all vascular plants for all sites and the three age classes.

Minimum reserve set using vascular plants

A minimum reserve set is the least number of sites required to reserve each species *n* times. An heuristic algorithm was used to investigate the minimal subset from 105 sites needed to reserve each species n = 1 and n = 2 times. Three species data sets were used: vascular plants, bryophytes species and vascular and bryophyte species. The procedure MSET in PATN was used (site richness algorithm, (Belbin 1991b; Belbin 1991a). MSET uses a continuous scale of 'complementarity' (Vane-Wright *et al.* 1991) where identical sites have minimum complementarity and non-identical sites have maximum complementarity. The site richness algorithm selects the site with the highest species richness and then selects subsequent sites based on those which have maximum complementarity with sites already in the reserve set.

Species composition

Presence/absence data for sites were grouped by cluster analysis using vascular plant and then bryophyte data. Matrices of dissimilarity were computed for both floras using Bray Curtis co-efficient (Bray and Curtis 1957). Wards group linkage method was used for clustering PCORD (McCune and Mefford 1999). The sorting strategy is also known as "error sum of squares" (Kent and Coker 1996). It is recognized that the Bray-Curtis co-efficient and the group linkage method are not strictly compatible (Faith *et al.* 1987). Wards method is a variance method, i.e. the group linkage measure is an estimate of the variance. Ward's method seeks to join clusters so that the total variance is minimized. The combination of Wards Method and Bray-Curtis co-efficient could be used because no hypotheses regarding the clusters are being produced. The clusters were only being used to investigate pattern in the data. Two other grouping methods were tested: Bray-Curtis and unweighted pair group method of averaging (UPGMA) and Bray-Curtis and Chord distance. These did not produce as meaningful communities. Vascular plant and bryophyte clusters were defined by truncation of the clusters at 0.5, 0.6 and 0.7. The significance of these communities at these truncations was then tested using an Analysis of Similarities (Clarke 1993) (ANOSIM in DECODA, Minchin 1990; 1000 permutations). For the vascular plant clustering, truncation at 0.5 was chosen as it produced 11 significantly different communities. For the bryophyte species cluster, truncation at 0.6 was chosen with 11 communities also selected. Percentage frequency data for vascular plants per community were tabulated. Species were sorted by grouping together those with greatest percentage frequency in community A, then B etc. The number of sites in common between each of the vascular plant and bryophyte communities were tabulated (Williams and Clifford 1971).

Non-metric multi-dimensional scaling (NMDS) was used to produce ordinations of species composition of all vascular plants and for bryophyte species. A measure of stress shows the extent to which the rank order of the sample distance disagrees with the rank order in the original Bray-Curtis matrix. Where stress is zero, the rank orders reach perfect agreement (Faith *et al.* 1987). This has been shown to be a robust method of analysis for species composition data (Minchin 1987). NMDS ordinations were performed in 1 to 4 dimensions using 10 different random initial configurations. A plot of stress versus the number of dimensions was used to select the dimension that adequately reflected the differences in species compositions among samples. All

ordinations were rotated (Procrustean analysis, DECODA, Minchin 1990) so the positions of sites best fitted those in the two-dimensional (n = 105) bryophyte ordination. Samples in ordinations are denoted by site number (see Appendix 8.2).

Bray-Curtis dissimilarity matrices for all sites and age classes per lifeform were correlated with each other and their degree of similarity tested using Mantel tests (*r*) with significance tested by permutation (1000 permutations, Sokal and Rohlf 1995; McCune and Mefford 1999). No dissimilarity matrix was generated for epiphytic ferns in age class a due to a lack of data.

Results

Species richness

A total of 128 vascular plant taxa and 240 bryophyte taxa were recorded from 105 sites (Appendices 8.3 and 8.4 respectively). The numbers of species by lifeform are shown in Appendix 8.5. Most of the vascular species richness was found in the ferns. Liverworts (133 species) were the most common bryophytes. Thirty-two vascular plants taxa were recorded only once. *Rubus fruticosus* (Blackberry) was the only introduced species. Thirty bryophyte taxa were recorded once. No introduced bryophyte species were recorded.

For all age classes, relationships between the species richness of vascular lifeform groups and bryophytes groups are weak. Vascular plant species richness is a significant but poor predictor of bryophyte species richness and liverwort species richness (Table 4.1, Figure 4.1a, b). Fern species richness is a better, but still weak, predictor of bryophyte species richness than any other lifeform group (Figure 4.1m). No single lifeform is a constant predictor of bryophyte species richness with differing forest ages (Table 4.1). All correlations between taxa groups are weak. For age class a (1 – 18 years), correlations among lifeform groups found only fern species richness is a significant predictor of bryophyte species richness (Figure 4.1m). For age class b (31 – 67 years), the species richness of all vascular plants is a poor but significant predictors of liverwort species richness only (Figure 4.1b). In old growth forest (age class c, > 110 years), fern species richness is not a good predictor of bryophyte species richness (Table 4.1, Figure 4.1m).

*Table 4.1. Variance explained (r^2) for species richness for lifeform groups. Number of sites (n) in age class: all age classes n = 105; age class a, 1 - 18 years, n = 18; age class b, 31 - 67 years, n = 54; age class c, > 110 years, n = 33. * p < 0.05, ** p < 0.01, *** p < 0.001, ns = not significant, '-' signifies a negative relationship.*

Lifeform species richness for all sites and per age class		Bryophyte species richness	Moss species richness	Liverwort species richness
All age classes	Number of species	240	107	133
All vascular plants	128	0.0782 **	ns	0.1344 ***
Trees	18	ns	-0 0571 *	ns
Tall shrubs	15	ns	ns	ns
Short shrubs	23	ns	-0 0955 **	ns
Non woody angiosperms	31	-0 2068 ***	-0.1162 ***	-0.1998 ***
All ferns	36	0 4183 ***	0.2439 ***	0.3963 ***
Ground ferns	14	0.0521 **	0.0708 **	ns
Epiphytic ferns	22	0 4369 ***	0 2135 ***	0.4525 ***
Age class a	Number of species	90	52	38
All vascular plants	79	ns	ns	ns
Trees	16	ns	ns	ns
Tall shrubs	10	ns	ns	ns
Short shrubs	18	ns	ns	ns
Non woody angiosperms	20	ns	ns	ns
All ferns	13	0.4019 **	0.2817 *	0.3658 **
Ground ferns	11	0.3799 **	0.2975 *	0 2913 *
Epiphytic ferns	2	ns	ns	0 3081 *
Age class b	Number of species	207	96	111
All vascular plants	99	ns	ns	0 2413 ***
Trees	15	ns	ns	ns
Tall shrubs	15	ns	ns	ns
Short shrubs	17	ns	-0.1012 *	ns
Non woody angiosperms	22	ns	ns	ns
All ferns	28	0 2204 ***	ns	0 3192 ***
Ground ferns	9	ns	ns	ns
Epiphytic ferns	19	0.2376 ***	ns	0 3489 ***
Age class c	Number of species	202	87	115
All vascular plants	76	0.1487 *	ns	0 1431 *
Trees	11	0.1570 *	ns	0.2649 **
Tall shrubs	10	0.3960 ***	ns	0.3739 ***
Short shrubs	9	ns	ns	0 1629 *
Non woody angiosperms	12	ns	ns	ns
All ferns	31	ns	ns	ns
Ground ferns	11	ns	ns	ns
Epiphytic ferns	20	ns	ns	ns

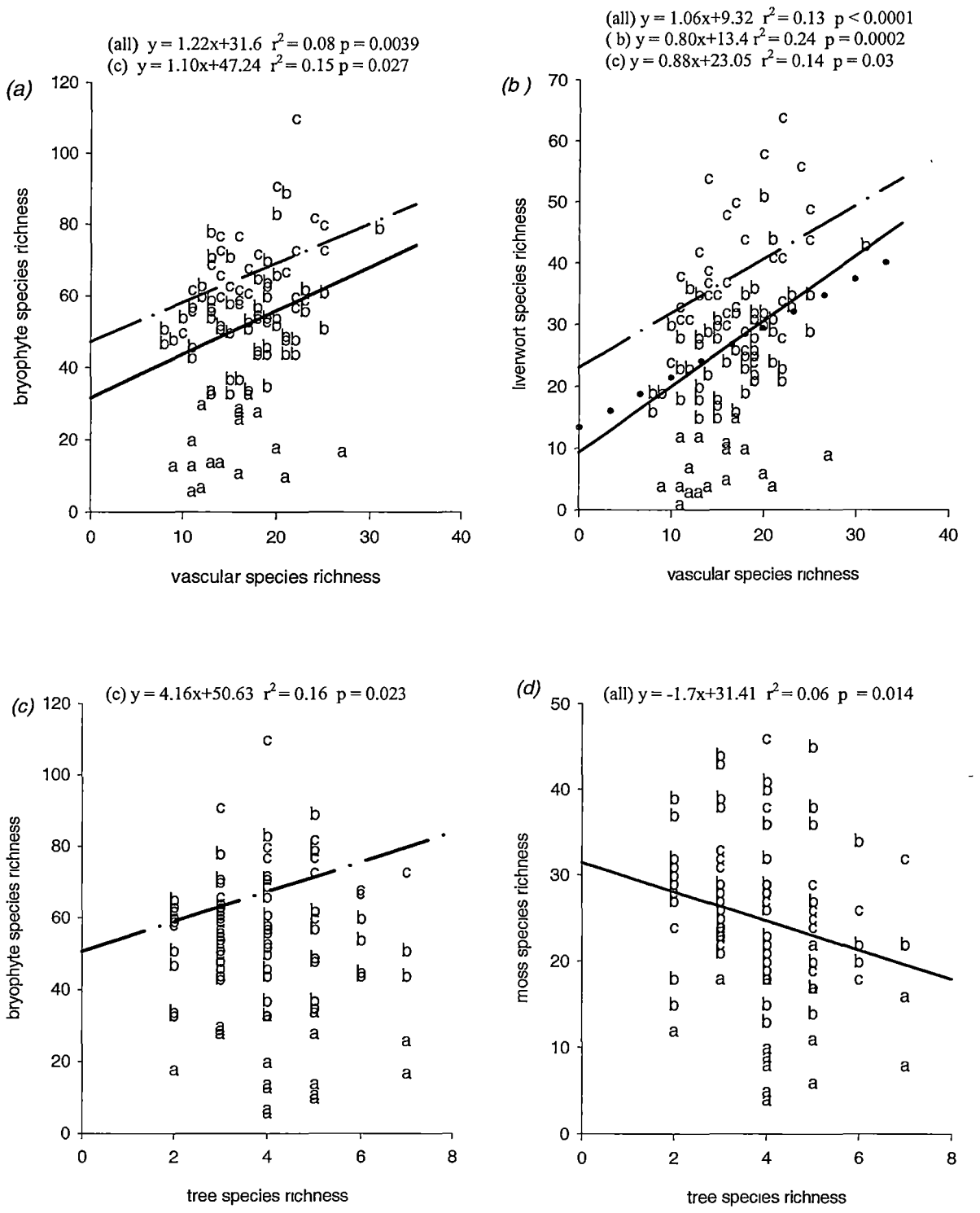
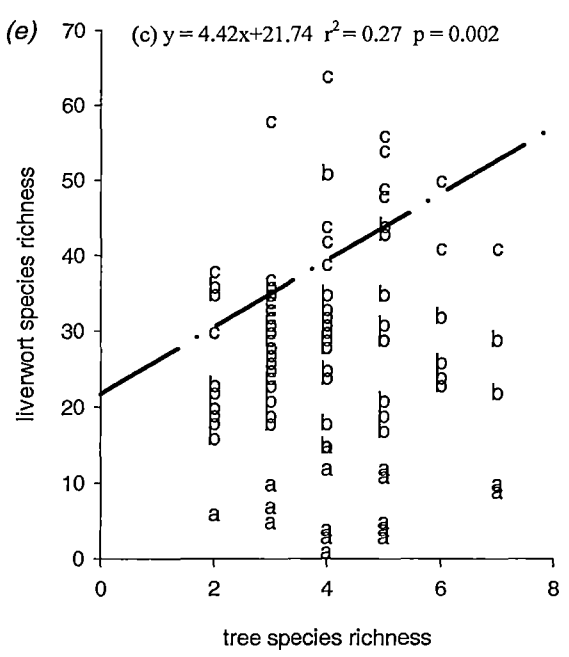
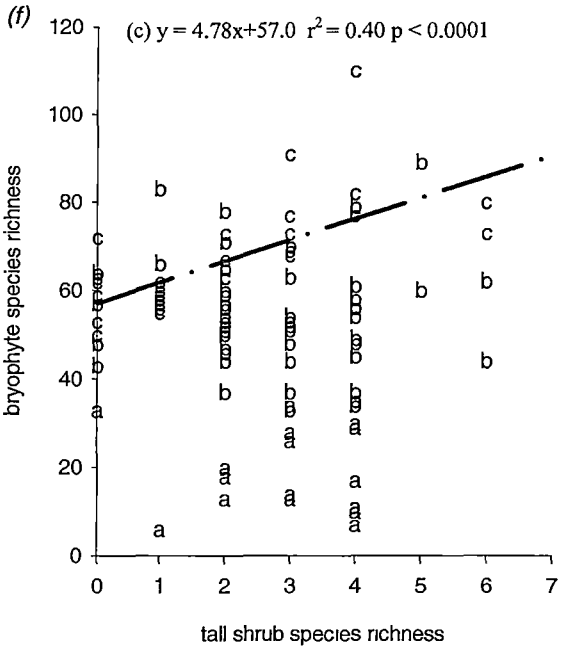
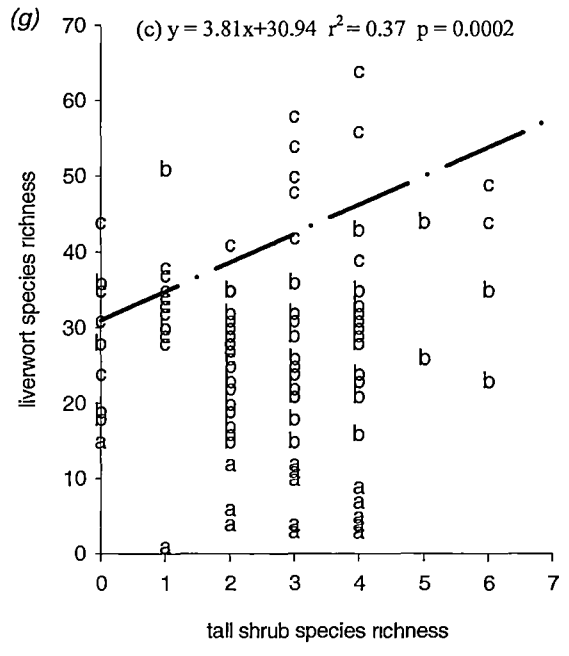
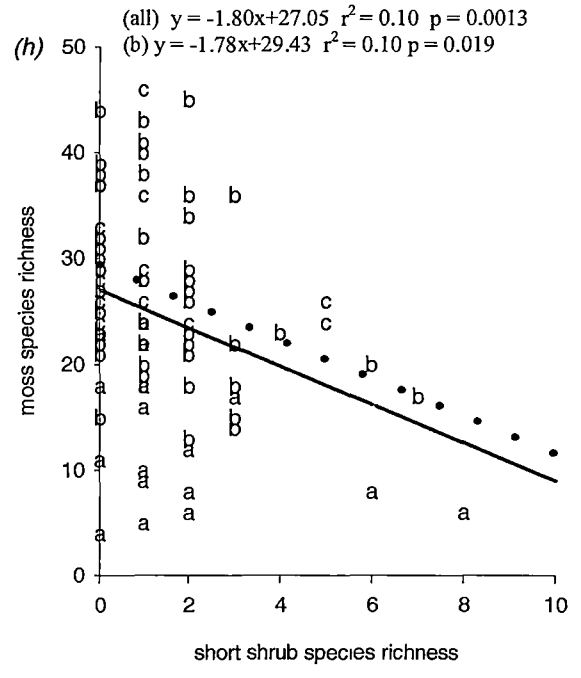


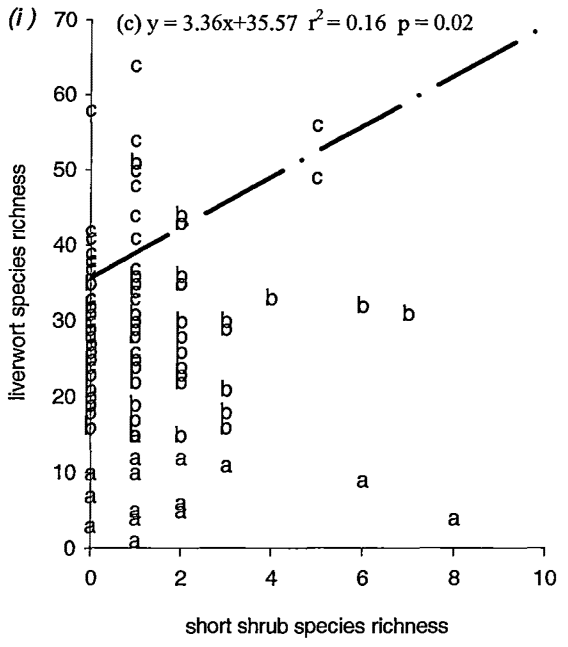
Figure 4.1. Regression of species richness for all sites and for each age class for vascular lifeform against species richness of bryophyte, moss and liverworts; (a - b) All vascular plants, (c -e) Tree, (f - g) Tall shrub, (h - i) Short shrub, (j - l) Non-woody angiosperms, (m - o) Ferns, (p - r) Ground ferns, (s - u) Epiphytic ferns. Letters in graph and next to equation indicate age class. Number of sites (n) in age class: all = all sites, n=105; a = 1 - 18 years, n = 18; b = 31 - 67 years, n = 54; c = > 110 years, n = 33. Solid line = all sites, dashed line = age class a, dotted line = age class b, dash dot line = age class c.

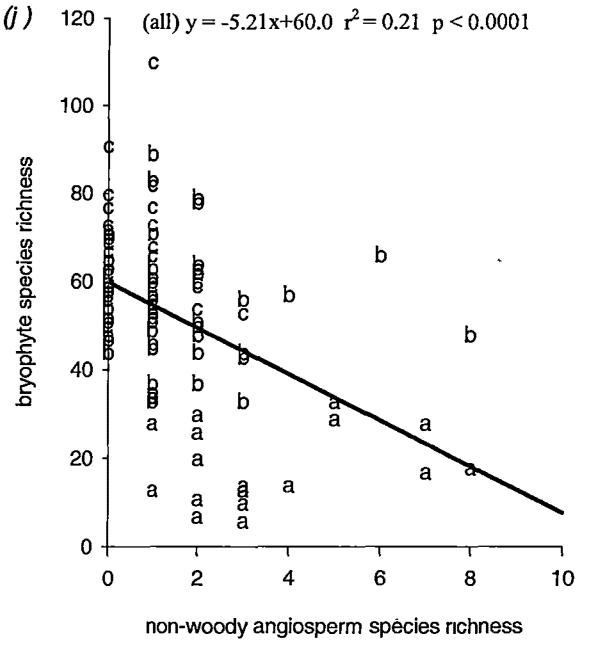

(e)
(c) y = 4.42x+21.74 r² = 0.27 p = 0.002
liverwort species richness
tree species richness

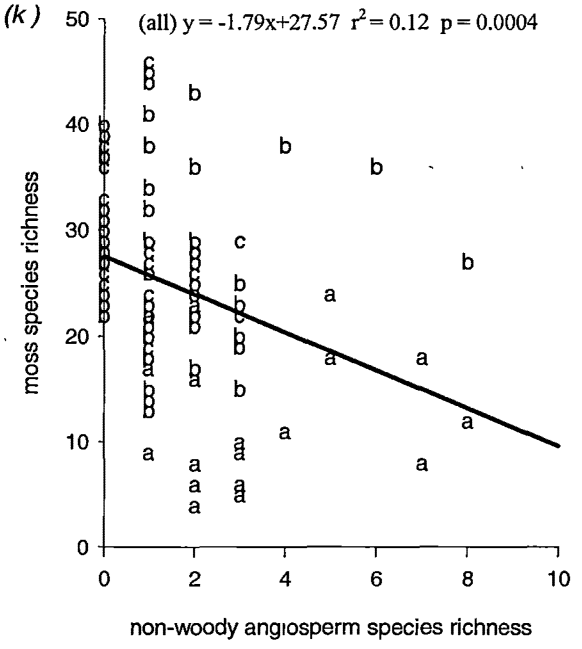

(f)
(c) y = 4.78x+57.0 r² = 0.40 p < 0.0001
bryophyte species richness
tall shrub species richness

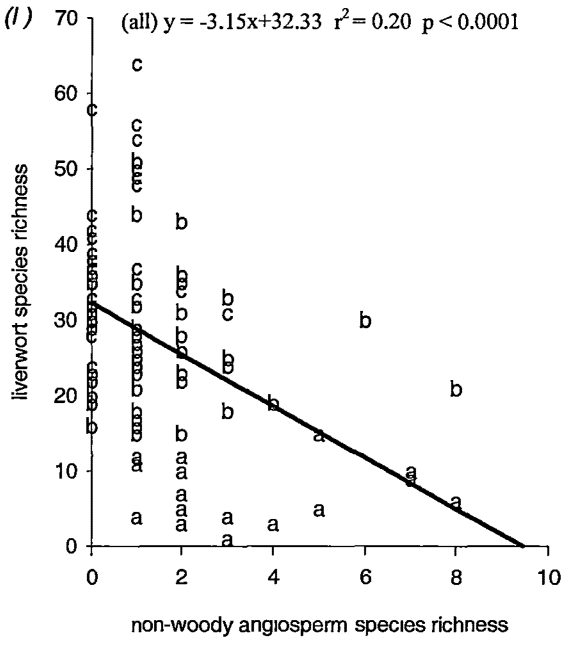

(g)
(c) y = 3.81x+30.94 r² = 0.37 p = 0.0002
liverwort species richness
tall shrub species richness

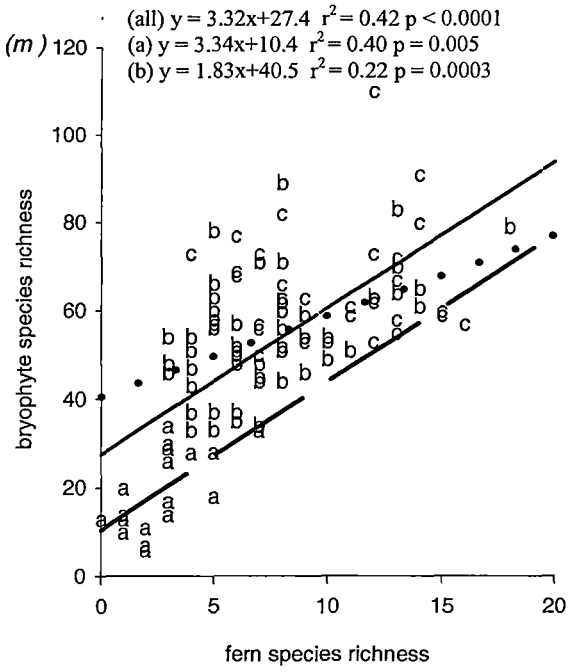

(h)
(all) y = -1.80x+27.05 r² = 0.10 p = 0.0013
(b) y = -1.78x+29.43 r² = 0.10 p = 0.019
moss species richness
short shrub species richness

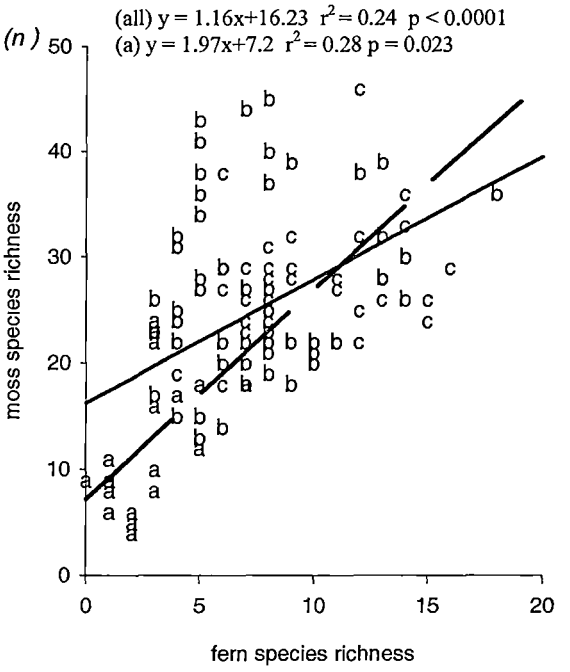

(i)
(c) y = 3.36x+35.57 r² = 0.16 p = 0.02
liverwort species richness
short shrub species richness

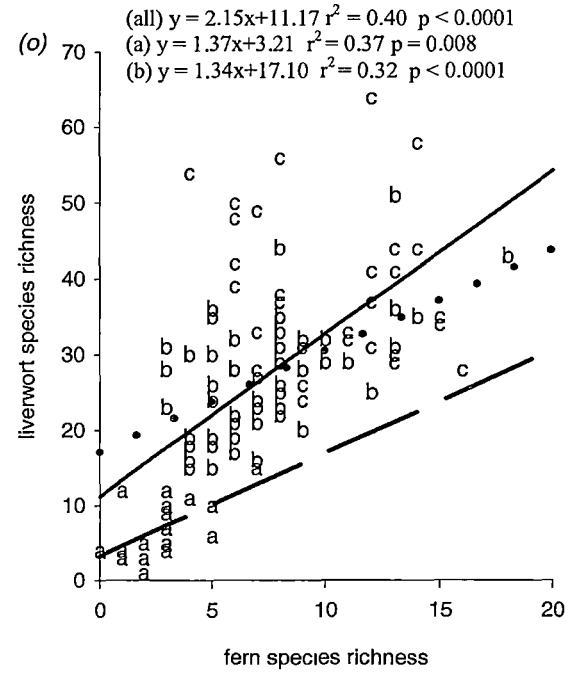

(j)
(all) y = -5.21x+60.0 r² = 0.21 p < 0.0001
bryophyte species richness
non-woody angiosperm species richness

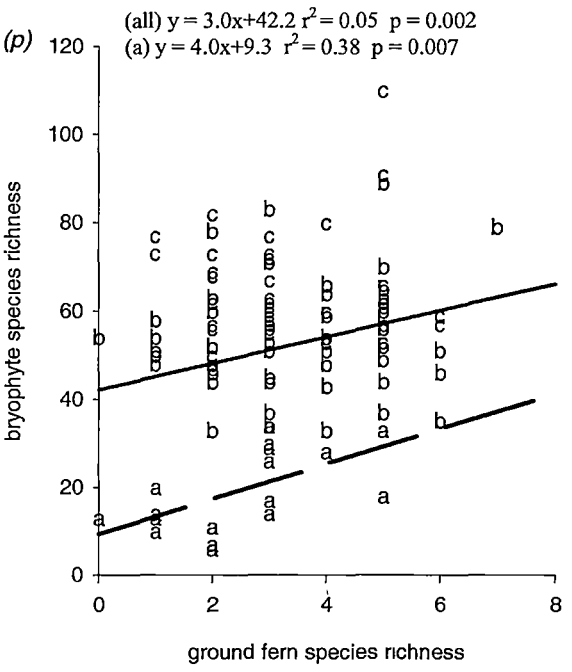

(k)
(all) y = -1.79x+27.57 r² = 0.12 p = 0.0004
moss species richness
non-woody angiosperm species richness

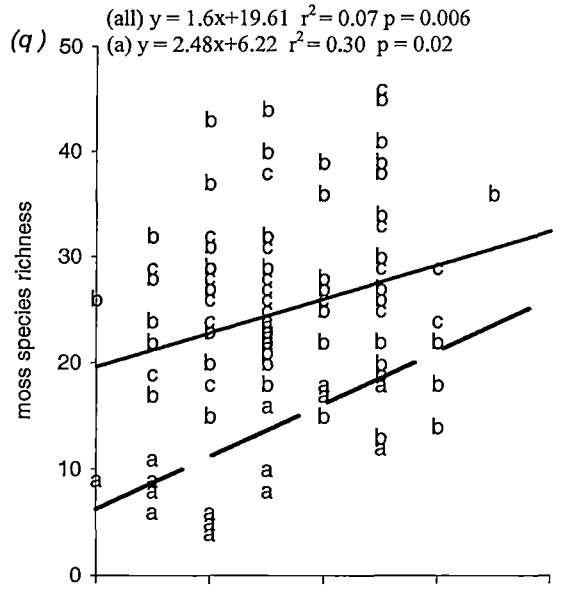

(l)
(all) y = -3.15x+32.33 r² = 0.20 p < 0.0001
liverwort species richness
non-woody angiosperm species richness

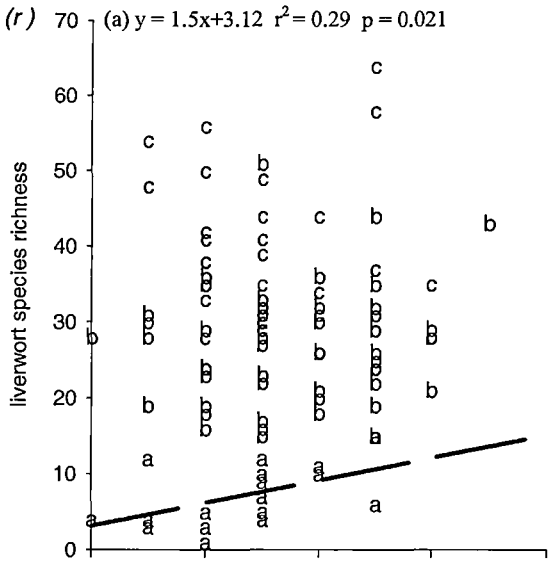

(m)
(all) y = 3.32x+27.4 r² = 0.42 p < 0.0001
(a) y = 3.34x+10.4 r² = 0.40 p = 0.005
(b) y = 1.83x+40.5 r² = 0.22 p = 0.0003
bryophyte species richness
fern species richness

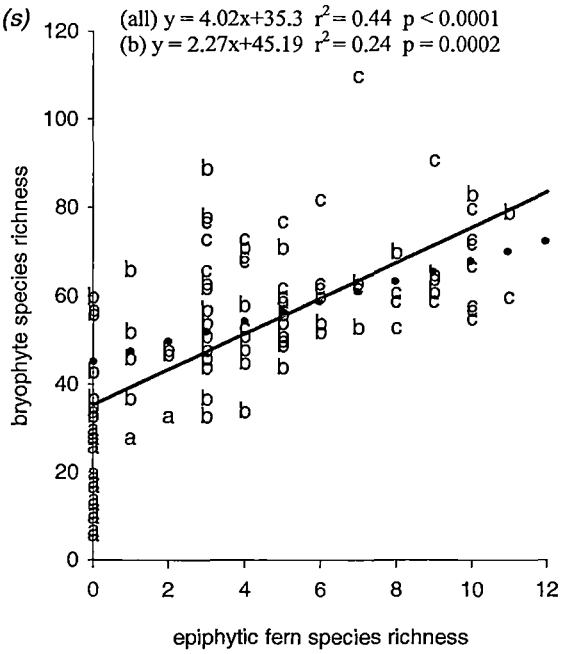

(n)
(all) y = 1.16x+16.23 r² = 0.24 p < 0.0001
(a) y = 1.97x+7.2 r² = 0.28 p = 0.023
moss species richness
fern species richness

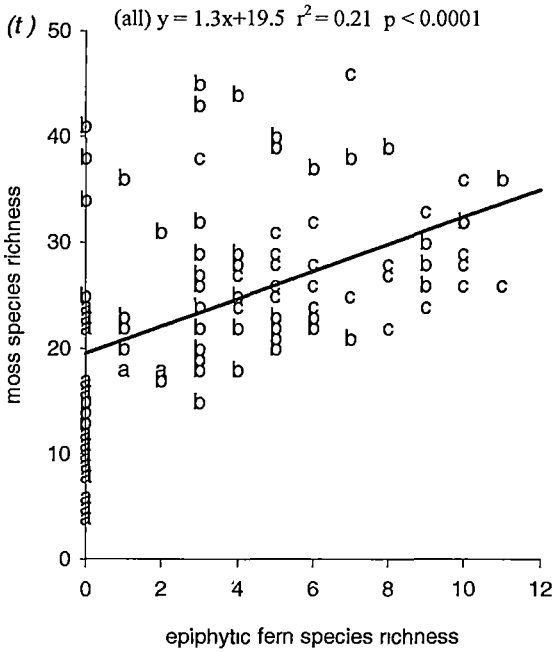

(o)
(all) y = 2.15x+11.17 r² = 0.40 p < 0.0001
(a) y = 1.37x+3.21 r² = 0.37 p = 0.008
(b) y = 1.34x+17.10 r² = 0.32 p < 0.0001
liverwort species richness
fern species richness

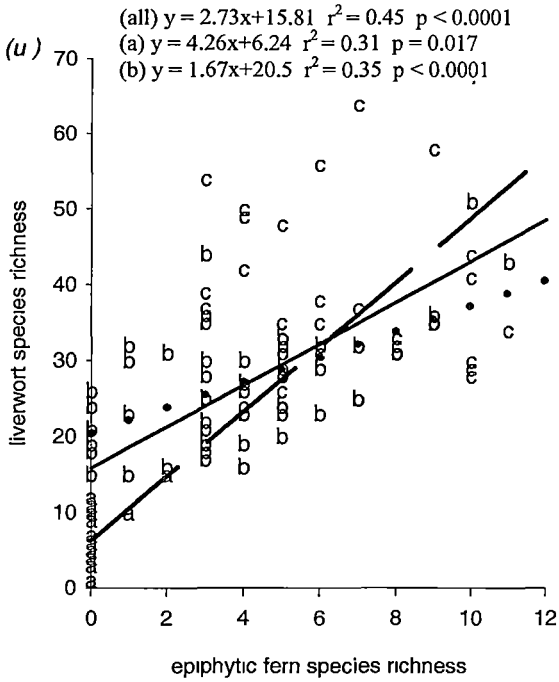

(p)
(all) y = 3.0x+42.2 r² = 0.05 p = 0.002
(a) y = 4.0x+9.3 r² = 0.38 p = 0.007
bryophyte species richness
ground fern species richness










(all) y = 2.73x+15.81 r² = 0.45 p < 0.0001
(a) y = 4.26x+6.24 r² = 0.31 p = 0.017
(b) y = 1.67x+20.5 r² = 0.35 p < 0.0001
(u)
liverwort species richness
epiphytic fern species richness
0
10
20
30
40
50
60
70
0
2
4
6
8
10
12

Minimum reserve sets

A minimum reserve set of 31 sites from a total of 105 was required to reserve all vascular plants once. These sites also reserved 199 bryophyte species (82.9%) at least once (Figure 4.2). The 31 sites consisted of 10 sites from age class a, 13 sites from age class b and 8 sites from age class c. The unreserved bryophyte species are listed in Table 4.2. Of the species unreserved, many are singletons. Some species however are not as uncommon, such as *Distichophyllum microcarpum* (present at 10 sites), *Thamnobryum pumilum* (10 sites), *Hypnodendron* spp. a (8 sites), *Adelanthus bisetulus* (6 sites), *Geocalyx caledonicus* (6 sites) and *Trachyloma planifolium* (6 sites). Thirty-three sites were required to reserve all bryophyte species once. These sites reserved 97 vascular plants (75.8%) at least once. The 33 sites consisted of 3 sites from age class a, 16 sites from age class b and 14 sites from age class c. Forty-one sites were required to reserve all 128 vascular plants twice. Thirty-two vascular plants only occurred once, thus the accumulative total of vascular species reserved twice was 224. The 41 sites also reserved 210 bryophyte species (87.5%) at least once (Figure 4.2). These sites included 13 sites from age class a, 16 sites from age class b and 12 sites from age class c. Sites included in the subset of 31 sites are repeated in the subset of 41 sites. The 30 bryophyte species unreserved in the subset of 41 sites were also not reserved in the 31-site subset. These 30 species are highlighted in Table 4.2. Most of the more common species unreserved in the 31-subset of sites are reserved in the 41-subset of sites. To reserve all 368 bryophyte and vascular species at least once, a subset of 49 sites were required, almost half of the number of sites sampled. The 49 sites include 11 sites from age class a, 23 from age class b and 15 from age class c.

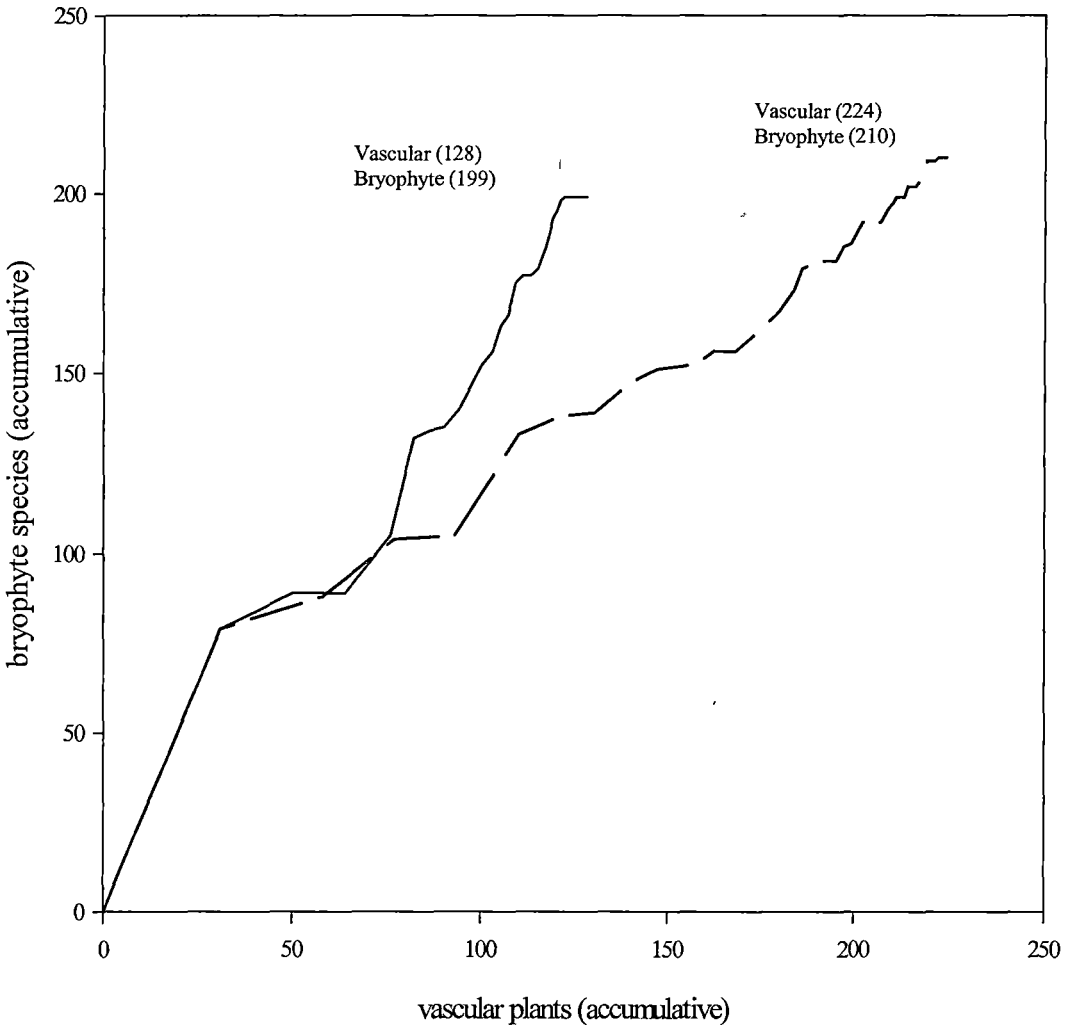


Figure 4.2. Species accumulation curves generated using the heuristic algorithm for the criteria of vascular plants reserved once (solid line, 31 sites, number of bryophyte species and vascular plants reserved at least once in brackets) and vascular plants reserved twice (dashed line, 41 sites, number of vascular plants reserved twice and bryophyte species reserved once in brackets). See text for details.

*Table 4.2. Bryophyte species unreserved in 31 - subset of sites (reservation of all vascular species at least once). * indicates species unreserved in subset of 41 sites (reservation of all vascular species at least twice).*

Bryophyte species	Percentage frequency in all sites (n = 105)	Species also unreserved in 41 sites subset
Distichophyllum microcarpum	9.52	
Thamnobryum pumilum	9.52	
Hypnodendron spp.	7.62	
Adelanthus bisetulus	5.71	
Geocalyx caledonicus	5.71	
Trachyloma planifolium	5.71	*
Hampeella alaris	4.76	
Macrocoma tenue ssp. *tenue*	3.81	
Metzgeria spp.	3.81	*
Treubia tasmanica	3.81	
Camptochaete deflexa	2.86	*
Daltonia splachnoides	2.86	
Dawsonia superba Grev. var. *pulchra* Zant.	2.86	*
Drepanolejeunea aucklandica	2.86	*
Calyptrochaeta brownii (Dix.) J.K. Bartlett	2.86	*
Bryum crassum	1.90	
Brachythecium salebrosum (F. Weber & D. Mohr) Schimp.	1.90	*
Heteroscyphus triacanthus	1.90	*
Lejeunea spp.	1.90	*
Psiloclada clandestina	1.90	*
Riccardia eriocaula	1.90	*
Brachythecium paradoxum	0.95	*
Bryum pseudotriquetrum	0.95	*
Cheilolejeunea albovirens	0.95	*
Chiloscyphus bispinosus	0.95	*
Chiloscyphus rupicolus (Steph.) Engel & Schust.	0.95	*
Diplasiolejeunea plicatiloba	0.95	*
Distichophyllum rotundifolium	0.95	*
Frullania monocera	0.95	
Frullania pentapleura	0.95	*
Grimmia trichophylla	0.95	*
Heteroscyphus argutus	0.95	*
Heteroscyphus sp. a	0.95	*
Kurzia sexfida	0.95	*
Orthodontium sp. a	0.95	*
Plagiochila fuscella	0.95	*
Radula retroflexa	0.95	*
Rhizogonium pennatum var. *aristatum*	0.95	*
Riccardia colensoi	0.95	*
Rosulabryum capillare (Hedw.) Spence	0.95	*
Sematophyllum uncinatum	0.95	*

Species composition

The 11 vascular plant communities (Appendix 8.6) are significantly different from each other ($R = 0.7546$, $p < 0.0001$) as are the 11 bryophyte communities ($R = 0.8152$, $p < 0.0001$). Descriptions of vascular communities are given in Appendix 8.6. Sites per vascular communities (coded A to K) and bryophyte communities (coded L to V) are listed in Appendix 8.2. The number of sites in common between vascular communities and bryophyte communities is greatest between communites J and O, and Kand P (Table 4.3). Many of these sites are old growth forest (Appendix 8.2).

Table 4.3. Number of sites in common between vascular plant and bryophyte communities defined by the cluster analysis. Vascular plant communities coded A – K, bryophyte communites coded L – V.

		Bryophyte communities										
		L	M	N	O	P	Q	R	S	T	U	V
Vascular plant communities	A	2		1				6	1	1		
	B									4		
	C		1					1		1	3	
	D		4		5							3
	E					3		2	4			
	F					2	2					
	G								3			
	H						3	1	2	2		4
	I	2		3	1	2						
	J			1	16	3						
	K			4	1	9	2					

The level of congruence between sites defined by bryophyte and vascular plant species composition is shown in Figure 4.3, by comparison of site numbers. Whereas there is no strict clumping of sites for vascular species composition (Figure 4.3a), the bryophyte ordination (Figure 4.3b) shows two clumps: the left groups are early regenerating sites (age class a) and those to the right are sites of age class b and c. The ordination of all bryophyte and vascular species (Figure 4.3c) is similar to the bryophyte ordination (Figure 4.3b). The subset of 31 sites required to reserve all vascular species at least once is superimposed (circles) onto both the vascular plant and bryophyte species ordinations (Figures 4.3a and 4.3b). Similarly, those sites required to reserve all bryophyte and vascular species (subset of 49 sites) are circled in Figure 4.3c.

Correlations between sites defined by vascular plant and bryophyte species composition are shown in Table 4.4. The greatest correlation was between bryophyte species and all vascular plant species ($r = 0.5191$, $p < 0.001$). Bryophyte species composition is only not significantly correlated with non-woody angiosperm species composition. No single vascular plant lifeform is a good constant predictor of bryophyte species composition for each age class (Table 4.4). For age class groups, the greatest relationship found was between the species compositions of all vascular plants and bryophytes in age class c ($r = 0.4886$, $p < 0.001$).

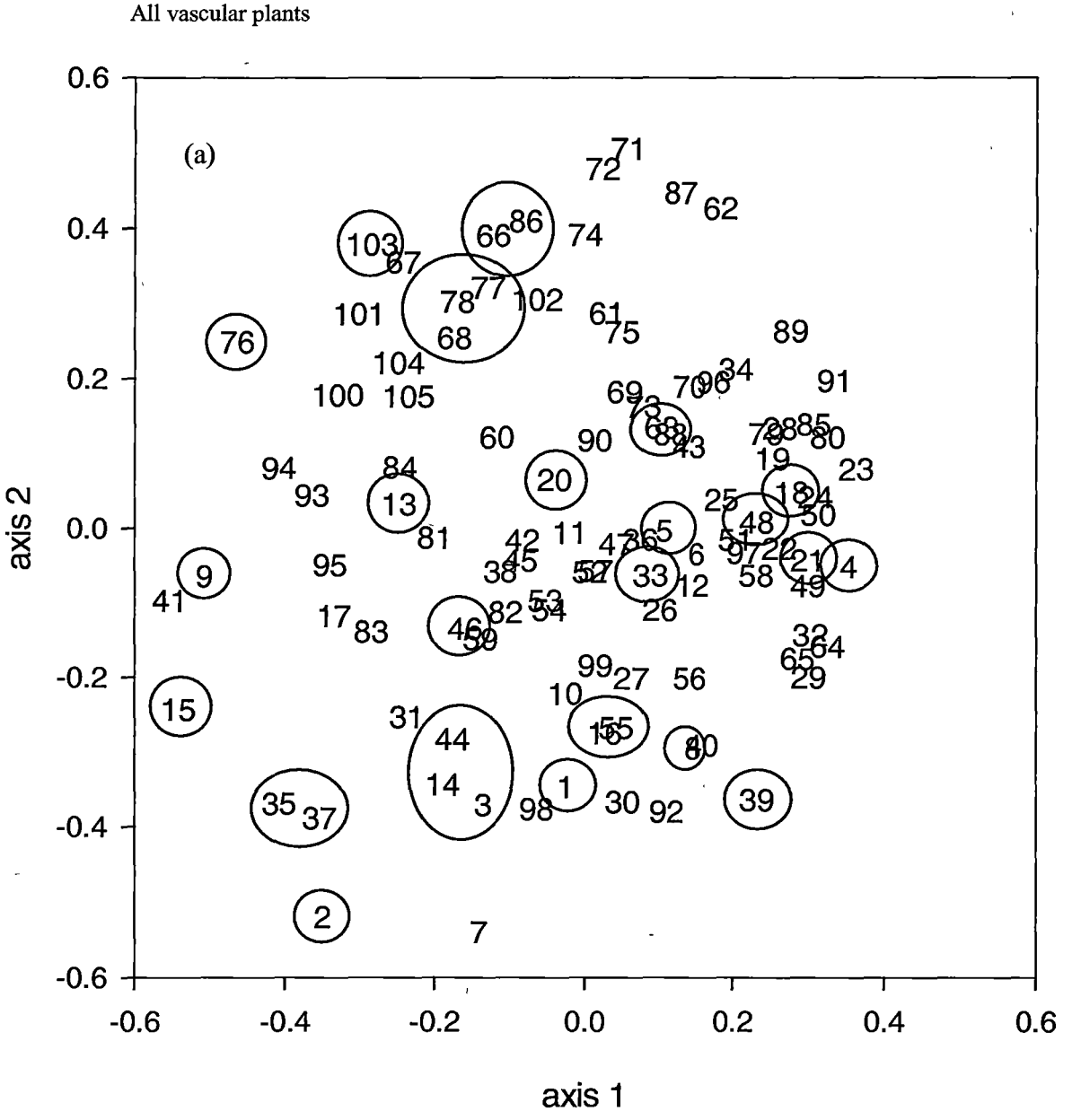
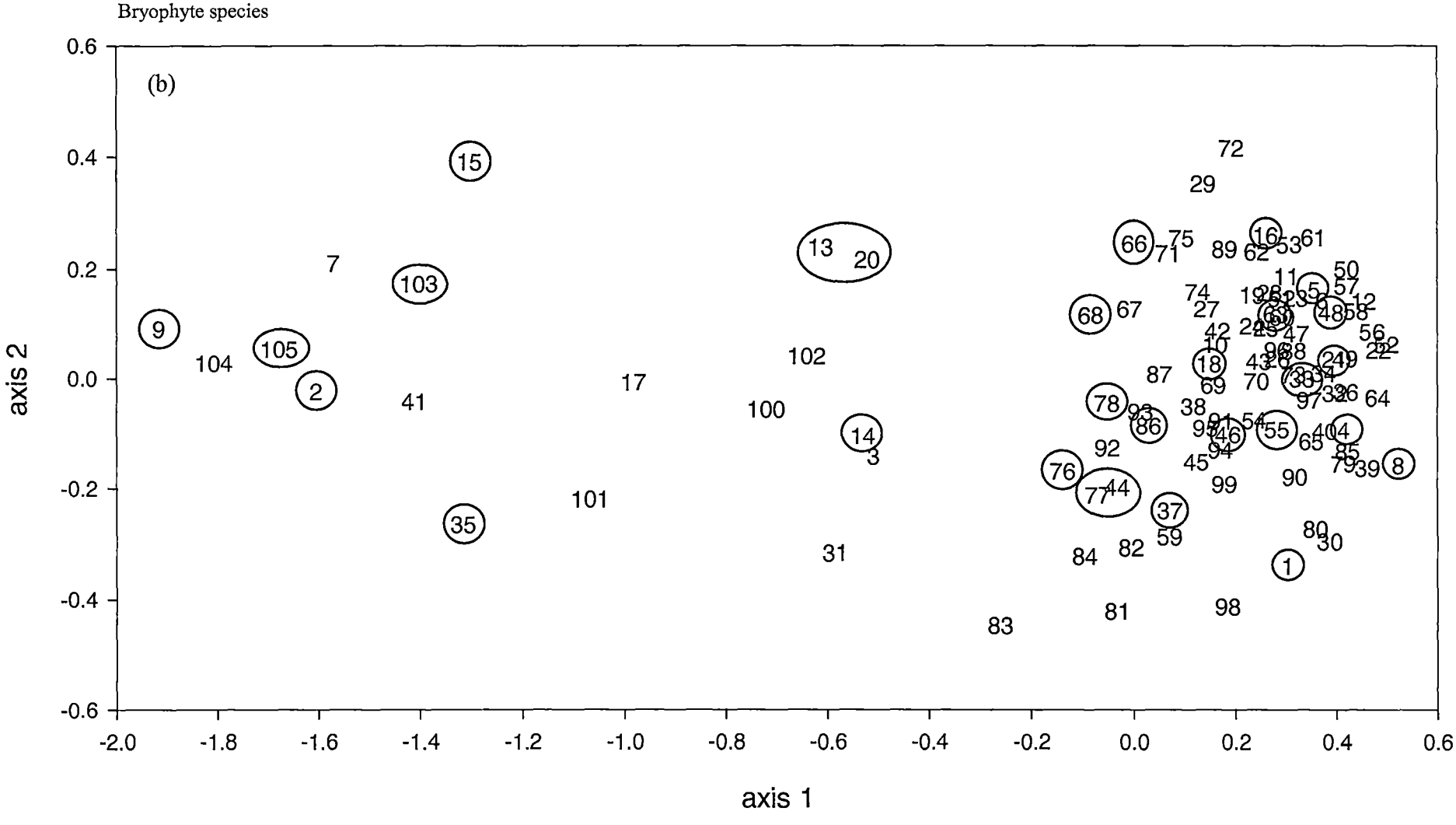


Figure 4.3. Two-dimensional ordinations for (a) all vascular plants (105 sites, 128 species, stress = 0.243), (b) all bryophyte species (105 sites, 240 species, stress = 0.136), (c) all bryophytes and vascular plants (105 sites, 328 species, stress = 0.152). Samples are labelled by site number (see Appendix 8.2). Circled sites identify those reserved in a the 31 site minimum reserve set (a and b) and 49 site minimum reserve set (c). See text for details.


Bryophyte species
(b)
axis 2
axis 1
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-2.0
-1.8
-1.6
-1.4
-1.2
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
15
7
103
9
105
104
2
41
17
13
20
102
100
14
3
101
35
31
72
29
66
75
16
61
71
89
62
53
11
50
74
5
57
27
68
67
48
58
42
47
56
10
18
87
69
70
78
38
64
97
86
54
55
65
92
94
45
76
44
77
90
99
37
59
80
30
84
82
1
81
98
83
8
79
39

All vascular plants and bryophyte species

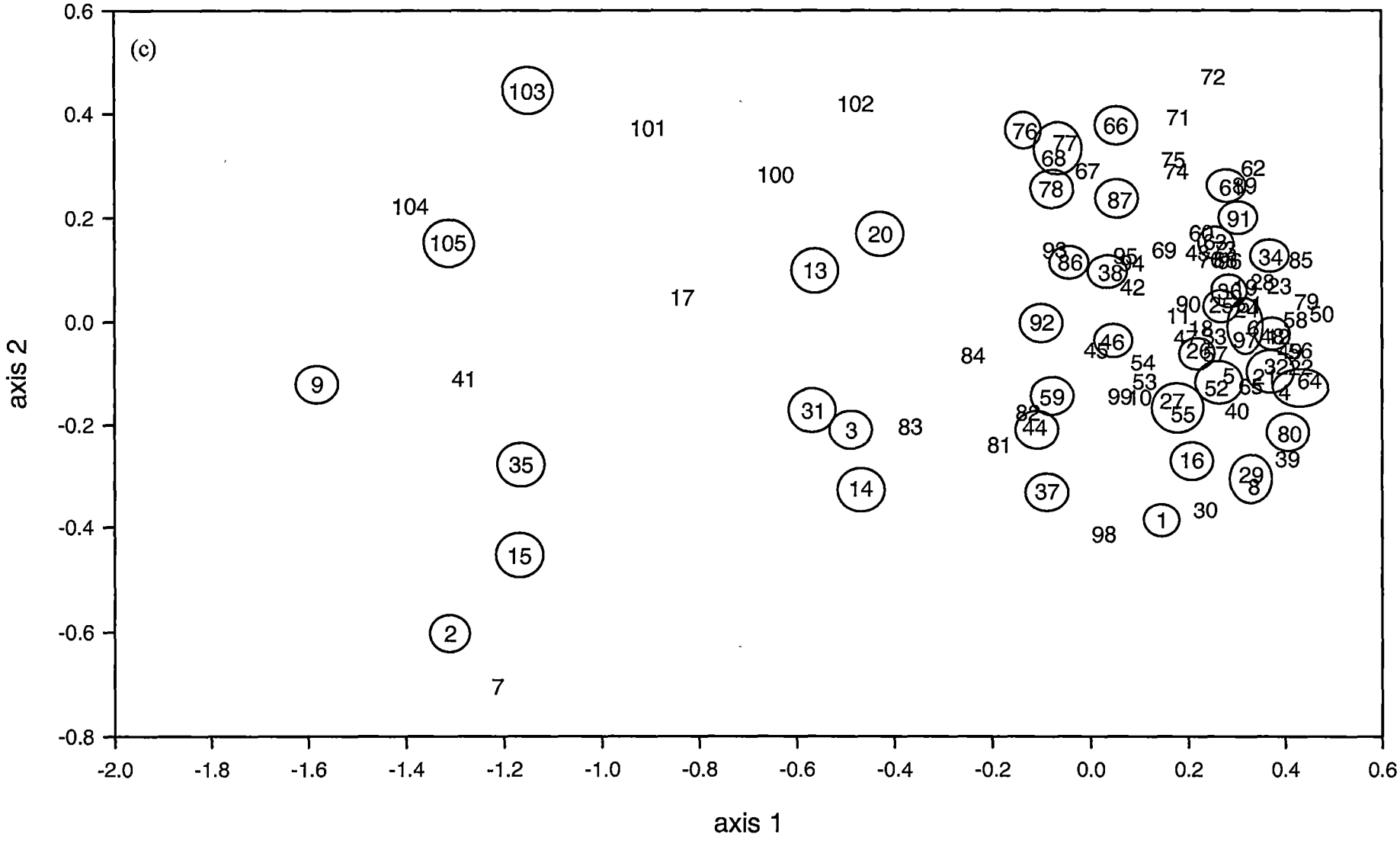


*Table 4.4. Mantel test statistic (r) of correlations of Bray-Curtis dissimilarity matrices for lifeform groups. Number of sites (n) in age class: all age classes n = 105; age class a, 1 - 18 years, n = 18; age class b, 31 - 67 years, n = 54; age class c, > 110 years, n = 33. * p = < 0.05, ** p = < 0.01, *** p = < 0.001, ns = not significant, n/a = not applicable. '-' indicates a negative relationship. Epiphytic ferns were not applicable in class a due to a lack of data (n = 2).*

	All vascular plants	Trees	Tall shrubs	Short shrubs	Non-woody angiosperms	All ferns	Ground ferns	Epiphytic ferns	Mosses
All classes									
Mosses	0.4670 ***	0.2658 ***	0.0694 *	0.1798 ***	ns	0.4547 ***	0.2566 ***	0.2743 ***	n/a
Liverworts	0.5137 ***	0.2881 ***	ns	0.2083 ***	ns	0.5206 ***	0.2820 ***	0.2942 ***	0.7991 ***
All bryophytes	0.5191 ***	0.2893 ***	0.0684 *	0.2070 **	ns	0.5184 ***	0.2896 ***	0.3266 ***	n/a
Age class a									
Mosses	ns	ns	ns	ns	ns	-0.1577 *	-0.1696 *	n/a	n/a
Liverworts	0.3004 **	0.1864 *	ns	0.2207 *	ns	ns	0.1846 *	n/a	0.2753 **
All bryophytes	ns	ns	ns	ns	ns	ns	ns	n/a	n/a
Age class b									
Mosses	0.3265 ***	0.2615 ***	0.2766 ***	ns	ns	0.1802 ***	ns	0.2257 ***	n/a
Liverworts	0.3838 ***	0.2028 ***	0.2077 ***	0.1197 *	0.1788 *	0.2532 ***	ns	0.2362 ***	0.5309 ***
All bryophytes	0.4258 ***	0.2692 ***	0.2716 ***	0.1281 *	ns	0.2498 ***	ns	0.2677 ***	n/a
Age class c									
Mosses	0.3700 ***	0.2403 ***	0.1850 ***	ns	ns	0.2810 ***	0.1788 **	0.2616 ***	n/a
Liverworts	0.4227 ***	0.3096 ***	0.2109 ***	ns	0.2603 *	0.2596 ***	0.2733 ***	0.1587 *	0.3892 ***
All bryophytes	0.4886 ***	0.3410 ***	0.2439 ***	ns	0.2107 *	0.3278 ***	0.2896 ***	0.2421 ***	n/a

Discussion

The results of the present study provide more evidence that bryophytes are a significant contributor to the biodiversity of mixed forest in Tasmania (Jarman and Kantvilas 1994; Jarman and Kantvilas 1997; Pharo and Blanks 2000), with the total number of bryophyte species almost double that of vascular plants. Bryophytes, like ferns, are more diverse in wet, moist environments with a substantial canopy cover (Smith 1982; Gradstein *et al.* 1989; Kessler 2001).

The species richness of all vascular plants appears to be a poor surrogate for both bryophyte species richness and liverwort species richness and not at all related to moss species richness, consistent with the results of Pharo *et al.* (1999) and Söderström (1981), but inconsistent with those of Fensham and Streimann (1997) and Ingerpuu *et al.* (2001). Humidity is known to have an effect on bryophyte richness and composition (Gradstein *et al.* 1989; Kessler 2001). The sampling of Fensham and Streimann (1997) and Ingerpuu *et al.* (2001) may extend over a much wider range of moisture conditions than in the cases of Pharo *et al.* (1999), Söderström (1981) and the present study.

Fern species richness showed a weakly positive relationship with bryophyte, moss and liverwort species richness. These results are consistent with those of Pharo *et al.* (1999) and Prendergast *et al.* (1993). Ferns and bryophytes require water for sexual reproduction and ecologically they are alike in their occupation of wetter environments (Scott 1994). Life cycle and morphology are also similar, with ferns near the beginning of their lifecycle being a gametophyte, like the dominant gametophyte stage of a liverwort.

Vascular plant lifeforms appear to be poor predictors of bryophyte species richness for different age classes. None is a predictor for every age class. Ferns and bryophytes both thrive in wet environments (Duncan and Isaac 1986). However fern species richness is not a good surrogate for bryophyte species richness in old growth forest. Fern and bryophyte species in old growth forest occupy similar substrates, such as logs, trees and soil (Duncan and Isaac 1986; Kessler 2001). The incidence of these substrates has been found to be similar in younger and old growth forests (Cooper-Ellis 1998; Vellak and Paal 1999). However, the substrates in old growth forest have been found to have a greater diversity of decay and more opportunistic niches, which is important to

bryophytes (Söderström 1988a; Crites and Dale 1998). Ferns may be more sensitive than bryophytes to the availability of the different substrates in old growth forest as they require more space for root establishment. Without root establishment, anchorage to the substrate, uptake of water and nutrients via vascular tissue and overall colonisation is restricted. In contrast, bryophytes absorb water and nutrients across the plant surface and have fine, filamentous rhizoids to attach the plant to the substrate surface. With this lack of dependence on roots, many of the common bryophytes are able to exploit more than one type of substrate (Scott and Rawley 1975; Ashton 1986).

With the possible exception of ferns, there is little congruence in richness between vascular plants and bryophyte species in mixed forest. Limitations in using species richness of one taxonomic group as a surrogate for another taxonomic group have been discussed (see Faith and Walker 1996), with suggestions that alternative methods be used to compare reserve sets for different groups. In the present study, 33 sites selected to reserve vascular species at least once, also captured a large proportion (82.9%) of bryophyte species at least once. Some more common bryophyte species, unreserved in this subset, were subsequently reserved in a larger subset of sites selected for reserving vascular plant species twice. Of the unreserved bryophyte species in the 33-subset and 41-subsets of sites, *Radula retroflexa* is recorded in the literature for Tasmania, but is as yet unrepresented by voucher specimens at the Hobart herbarium although field observations have been made (J. Jarman pers comm. 2003). Little is known of its distribution in the state (Mosçal and Kirkpatrick 1997). For many bryophyte species there is insufficient data on distribution and the ecology to critically evaluate their conservation status (Scott *et al.* 1997).

Of those sites required to reserve all vascular species at least once, there were more sites required from younger forests than forests older than 110 years. A similar result was found when selecting reserves based on preserving both vascular and bryophyte species at least once. It is not surprising that these younger forests reserve a greater variety of species than older forests; these regenerating forests represent seral stages of wet eucalypt forest after disturbance by fire. Fire determines the resulting community through intensity, the ability of vascular species to resprout (Ough 2001), and the distribution and availability of propagules. Therefore, these forests include a range of vascular and bryophytes species because of disturbance by fire. Forest type classification in Tasmania, including wet eucalypt forest, is primarily based on vascular

plants floristics (Kirkpatrick *et al.* 1988; Jackson 1999). Approximately 64% of wet eucalypt old growth forest (age class c, > 110 years), and 14% of regrowth (20 – 100 years) is reserved in Tasmania (Resource Planning and Development Commission 2002). Of the remaining unreserved wet eucalypt forests, 0.39% of regenerating (0 – 20 years) and 61% of regrowth (20 – 100 years) forests are in state forest and 97% of regenerating and 24% of regrowth forests are on private property (Resource Planning and Development Commission 2002). Both state and private forests have been or may be subject to timber harvesting followed by the establishment of plantation forests or clearing for agriculture. These younger forests of age class a and b are a result of only one disturbance event. Further disturbance through removal of forest or conversion to plantation forest or agriculture, would involve loss of habitat. Clearing has been primarily responsible for the loss of bryophyte habitat (Scott *et al.* 1997).

At all sites, the species composition of all vascular plant lifeforms, apart from non-woody angiosperms, is significantly correlated with bryophyte species composition, but many correlations are weak. Similar weak relationships between lifeform groups were found by a North American study (McCune and Antos 1981). Weak significant correlations were found between bryophyte species composition and vascular plant species composition. This result is consistent with, but not as strong as, another Tasmanian study where the vascular composition of different rainforest communities was a good surrogate for bryophyte species composition (Jarman and Kantvilas 1995b). Host specificity was one factor assumed to explain the differences in epiphytic flora between the rainforest communities.

In the present study, bryophyte species composition for a particular age class is only weakly predicted by the species composition of a vascular lifeform group from the same age class. No single vascular lifeform species composition is a predictor of bryophyte species composition for all of age classes a, b and c. There is a rapid change in vascular plant species composition at these sites with age since disturbance. This is influenced by surviving species or those present before disturbance and colonising species or those not found in the forest before the disturbance but which now invade and rapidly settle in the new environment. The establishment of some vascular plant seedlings is also retarded by bryophyte species that blanket the forest floor and 'push' over establishing seedlings (Cremer and Mount 1965). These forest dynamics may explain the lack of

congruence in species compositions between bryophyte species and vascular plant lifeforms.

The present study addressed the question of whether the species richness of mosses, liverworts and bryophytes as a group was significantly related to the species richness of all vascular plants and vascular plant lifeform groups. Little congruence in richness between vascular plants and bryophyte species in mixed forest was found, with fern species richness only weakly positively related to bryophyte, moss and liverwort species richness. Given the greater number, greater diversity, the smaller size and the difficulty of accurate field identification of bryophyte than vascular plant species, including them in field surveys in these forests can be particularly time consuming. Although ferns have the potential to be useful indicators of bryophyte species richness in routine surveys, highlighting individually fern rich areas may include more common bryophyte taxa and exclude, or insufficiently include, those taxa with more dispersed distributions. Therefore, the use of species richness as a surrogate for bryophytes in wet eucalypt forest is limited.

Chapter Five

Influence of substrate and age of stand on bryophyte species composition in Tasmanian mixed forest.

Abstract

There have been few temporal studies investigating the species composition and distribution of bryophytes on different substrates and no studies have been undertaken in the southern hemisphere. The species distribution and species composition of bryophytes on various substrates from three age classes of mixed forest was investigated in Tasmania. Substrate sampling included 15 vascular species, logs, fallen branches, ground, rocks, upturned root bases, stumps, roots and dead trees. A total of 49 substrate/age class groups were sampled. Twelve substrates were found only in a single age class. On two of these substrates, two bryophyte species that did not occur in other forest age classes were found. Many other species were found only to occur on one substrate type, but these substrate types were found in more than one age class. Two species, Rhizogonium distichum *and* Balantiopsis diplophylla *preferentially occurred on logs and on the ground, respectively, in age class b forest (33 – 67 years). Fourteen moss and fourteen liverwort species preferentially occurred on logs in age class b. Most of these species also had a preference for logs in old growth forest (> 110 years). Similar bryophyte species preferred* Eucalyptus obliqua *and* E. regnans *trees of 33 – 67 years as a substrate. A number of the same bryophyte species were positively associated with fallen branches, logs and ground in both age class b forest and old growth forest. Bryophyte species composition differed between many substrate/age groups. In particular, old growth* Nothofagus cunninghamii *and* Atherosperma moschatum *trees had species compositions that were significantly dissimilar to a large number of substrate/age class groups. Bryophyte species composition on the ground differed between all age classes. Some substrates, such as tall shrubs and trees of the same species, had similar species compositions within and between age classes. Bryophyte species compositions of* Eucalyptus *spp. were not similar, with differences for the same tree species detected across age class. Logs in age class b and old growth forest had weakly dissimilar species compositions. Consistent with previous literature, bark type affects species composition.*

Introduction

Bryophyte species composition on different substrates has been the focus of many studies in the northern hemisphere (Billings and Drew 1938; Pike *et al.* 1975; Palmer 1986; Söderström 1988b; Söderström 1993; McAlister 1997; Peck 1997; Rambo and Muir 1998b; Qian *et al.* 1999) and, to a lesser extent, in the southern hemisphere (Scott 1970; Beever 1984; Ashton 1986; Pharo and Blanks 2000; Jarman and Kantvilas 2001b; Pharo and Beattie 2002). In mixed forest, the majority of research has focused on the composition and succession of vascular plants (Gilbert 1959; Jackson 1968; Mount 1979; Hill and Read 1984; Hickey 1994; Ough 2001). Mixed forest is defined as vegetation with a rainforest understorey and eucalypt overstorey (Gilbert 1959). Fires at intervals of 100 - 350 years maintain mixed forest (Gilbert 1959; Jackson 1968). The older stands of mixed forest are termed 'old growth forest' and have great cultural and natural significance. However, if there is an absence of fire for more than approximately 400 years, the eucalypts of old growth forests die out, leaving rainforest (Jackson 1968). In the definition used in the present paper, Old growth mixed forest is at least 110 years old without any signs of human disturbance.

Studies of logs (coarse woody debris) and trees have found bark texture to be important in determining bryophyte species distribution and composition (Söderström 1988b; Wolf 1994; McAlister 1997). In eastern North America, a lack of variation in bark texture is thought to explain why bryophyte species composition does not vary by host tree (Slack 1976). Bark texture is thought to influence propagule establishment, with crevices of rough bark providing propagules with the opportunity for attachment (Söderström 1988b). Some bryophyte species have been found to be substrate specific, where it is not the nature of the substrate, but most probably the microclimatic conditions associated with that substrate that is responsible (Beever 1984; Söderström 1993; Wolf 1994).

Where more than one substrate has been investigated, bryophyte species composition has been found to be different between substrate types (Ashton 1986; Söderström 1988b; Qian *et al.* 1999; Pharo and Beattie 2002). In mature *Eucalyptus regnans* forest, Ashton (1986) studied the species composition of different substrates (tree trunks, soil patches and rocks) and topographically different areas. In eastern Australian forests, strong differences in species composition were found between tree bases, rocks, fallen

branches, ground and logs (Pharo and Beattie 2002). However, a study of cryptogams on decaying wood in forests of southern coastal British Columbia found them identical to cryptogam forest floor communities (Qian *et al.* 1999).

The bryophytes growing on varying substrates in Sweden were believed to be influenced by the proximity of neighbouring substrates (Söderström 1981). Thus, normally epixylic species colonising small wood fragments may instead be found apparently growing on the ground. Söderström (1981) also found that size, aspect of substrate and prevailing climate conditions influenced the substrate preference of bryophytes.

A number of northern hemisphere studies have investigated species composition on substrates in different aged forests (Söderström 1988a; McAlister 1997; Rambo and Muir 1998a; Rambo and Muir 1998b; Boudreault *et al.* 2000). The composition of bryophytes on fallen logs, forest floor substrates or stumps in forests of different stand ages has been found to be significantly different (Söderström 1988a; McAlister 1997; Rambo and Muir 1998a). Other studies found no difference (Vellak and Paal 1999). Some of these temporal studies found differences in amount of substrate and substrate condition to be influential in determining bryophyte species composition and distribution. The difference in amount of decaying wood found in unmanaged compared to managed stands is thought to be one factor influencing species preference for a stand type (Söderström 1988a). Changes in substrate condition over time are also believed to play a role (Rambo and Muir 1998b). In a study of boreal forest epiphytic cryptogams of south-western Quebec, there was a difference in species composition within the oldest stand due to a mixture of young and old trees on some sites (Boudreault *et al.* 2000). Although not directly investigating variation on composition between stand ages, in forest aged between 50 and 290 years in north-western Oregon Peck (1997) found host preferences were more for size of plant trunks than species.

Previous Australian studies have looked at the bryophyte composition on various substrates (Ashton 1986; Jarman and Kantvilas 2001b; Pharo and Beattie 2002) but have not included a temporal component. The present paper is the first to investigate bryophyte species composition and distribution on substrates in different ages of wet eucalypt forest. The following questions are addressed: (1) are there substrates/species only found in one age class and do these unique substrates have species not found in

other age classes? (2) are there species that would disappear without a particular substrate or group of substrates? (3) in similar aged forest, is there a difference in species composition between substrates? (4) does the substrate preference of species change between different ages of forest?

Materials and Methods

Study area

Data were collected from 105 sites (Chapter 3, Figure 3.1). Details for the 105 sites regarding methods of site selection, site locations, disturbance history and dominant *Eucalyptus* species are given in Chapter 3. Mean annual temperature ranges from 6.1 to 12.1 °C (mean 9.86 ± 0.15 °C) and mean annual rainfall ranges from 1104 to 2104 mm (mean 1471.21 ± 18.31 mm). Site characteristics, rainfall and temperature data are given in Appendices 8.1 and 8.2.

Vegetation sampling

Fieldwork was undertaken from October 1999 to February 2000 and October 2000 to March 2001. At each site, the forest was sampled for the presence/absence of bryophytes and vascular plants using three transects, 25 m x 2 m. Transects were located at a distance > 50 m from the road edge. Each transect was placed perpendicular to the slope. Presence/ absence data from the three transects per site were pooled to calculate site values. Logs, fallen branches, stumps, vascular plant species, rocks, dead trees, treeferns, roots, upturned root bases and ground were all sampled separately within each transect. Logs were defined as greater than 10 cm diameter and fallen branches were less than 10 cm diameter. Vascular plant species were divided into lifeform groups; tree (greater than 5 m tall, single stemmed), tall shrub (greater than 8 m tall, multi-stemmed), short shrub (less than 2 m tall, multi stemmed from base, woody species). Often more than one example of a substrate was found along a single transect, so the bryophyte species found on all examples of that substrate, for that transect, were aggregated. Treeferns (*Dicksonia antarctica*) were divided into standing (vertical, alive), fallen (horizontal, dead) and stumps (vertical, dead). Treeferns have a fibrous trunk of roots that is obscured in young treeferns by dead fronds hanging down (skirts), brushing the trunk. Treeferns with skirts were not sampled. If all treeferns within the

transect had skirts, nearby alternatives were sought. Ground included all bare soil within the 25 m x 2 m area. No bryophytes were found on leaf litter.

One hundred and sixteen substrate/age classes occurred in a total of 1300 samples. The distribution of samples per substrate/age class was not equal because all substrates were not present in all forest age classes. Only substrates with 10 or more samples for at least one age class were included in analyses. The reduced total of samples was 1118, distributed over 49 substrate/age classes. Nomenclature follows Dalton *et al* (1991) for mosses, Ratkowsky (1987) for liverworts and Buchanan (1999) for vascular plants except where authorities are given.

Environmental variables

Environmental measurements were recorded from each of the three transects. A single value for each site was used for latitude (° east), mean annual temperature (°C), mean annual rainfall (mm) and rainfall of the driest month (mm). A mean value was used for the remaining variables, aspect (°), slope (°) and altitude (m). Details of variables are given in Table 5.1. For further details of variables see Chapter 2.

Analysis

Species - substrate association

The significance of the associations between individual bryophyte species and individual substrate/age classes was determined using chi square in all cases where expected values were ≥ 5.

Table 5.1 Environmental variables for 105 sites.

	All sites		Age class a		Age class b		Age class c	
	Mean ± SE	Range	Mean ± SE	Range	Mean ± SE	Range	Mean ± SE	Range
Altitude (m)	334.06 ± 19.02	40.00 – 660.00	385.61 ± 48.08	100.00 – 647.00	338.80 ± 27.18	60.00 – 660.00	298.18 ± 31.37	40.00 - 633.00
Aspect (°)	192.41 ± 7.71	18.33 – 350.00	176.02 ± 21.82	40.00 – 331.67	201.41 ± 9.24	80.00 – 316.67	186.62 ± 15.34	18.33 – 350.00
Mean annual temperature (°C)	9.86 ± 0.15	6.10 – 12.10	9.96 ± 0.31	8.30 – 12.10	9.77 ± 0.20	7.50 – 12.10	9.95 ± 0.30	6.10 - 12.10
Mean annual rainfall (mm)	1471.21 ± 18.31	1104.00 – 2104.00	1457.56 ± 62.08	1104.00 – 2104.00	1456.82 ± 24.28	1147.00 – 1888.00	1502.21 ± 26.59	1147.00 - 2104.00
Rainfall driest month (mm)	69.84 ± 0.95	51.00 – 94.00	68.83 ± 2.19	51.00 – 94.00	69.97 ± 1.42	55.00 – 83.00	70.18 ± 1.51	55.00 - 94.00
Slope (°)	9.78 ± 0.619	1 - 26	7.65 ± 0.99	1.67 – 16.00	10.78 ± 0.89	1.00 – 26.00	9.29 ± 1.19	1.33 - 25.67
Latitude (° east)	42.282566 ± 0.09	40.971653 - 43.248477	42.172251 ± 0.20	40.971653 - 43.228108	42.427563 ± 0.12	40.991804 - 43.248477	42.105471 ± 0.15	41.0388 – 43.24095

Substrate species composition

Non-metric multi-dimensional scaling (NMDS) was used to produce an ordination of species composition of 1118 substrate samples (PC-Ord, McCune and Mefford 1999) using the Bray-Curtis dissimilarity co-efficient (Faith *et al.* 1987). NMDS was also used to produce a second ordination of environmental variables, using the Gower metric (DECODA, Minchin 1990). Both NMDS ordinations were performed in 1 to 4 dimensions using 10 different random initial configurations. A plot of stress versus the number of dimensions was used to select the dimension that adequately reflected the differences in species compositions among samples. For species composition data, a three dimensional ordination with the mean of the ordination scores for each substrate/age class was selected. A two-dimensional ordination was selected for the environmental variable data.

Analysis of Similarities (ANOSIM) (Clarke 1993), was used to test for significant differences between the 49 substrate/age class groups (species composition data) and forest age class using DECODA (Minchin 1990, 1000 permutations). The Bray-Curtis dissimilarity co-efficient was used for species composition data and the Gower metric for environmental variable data. ANOSIM quantifies the differences in floristics between groups of samples and compares those differences to those found within groups. ANOSIM constructs a test statistic (R), which is a measure of the degree of separation of groups of sites. The denominator is such that R can never lie outside the range –1 to 1. If R = 1 then all quadrats within groups are more similar to each other than any quadrats from different groups. If R = 0, then the null hypothesis is true and the dissimilarities between and within groups will be the same on average. It is possible for R to be significantly different from zero yet inconsequentially small, if there are many quadrats at each site (Clarke 1993). Values smaller than zero indicate greater dissimilarity among samples within groups, than occurs between groups. The significance of R was calculated by comparing the test statistic to 1000 random permutations. The significance levels of pairwise tests are not adjusted for multiple comparisons. Values of 'p' falling close to 0.05 need to be interpreted with care (Clarke 1993). Substrate age class groups whose pairwise comparisons were not significantly different ($p > 0.05$) were plotted with connecting lines between each pair.

Results

A total of 240 bryophyte species were recorded from the original 116 substrate/age classes. With the reduction of substrate age classes to 49, 239 bryophyte taxa remained. One liverwort, *Cheilolejeunea campbelliensis,* was removed from the analysis because it occurred only once on *Phyllocladus asplenifolius* (tall shrub) in old growth forest. The frequency of samples per substrate/age class is listed in Table 5.2.

There were 12 substrates only found in a single age class. Ten substrates were in age class b: *Acacia dealbata* tree (20 samples), *Acacia melanoxylon* tree (20), *Eucalyptus delegatensis* tree (10), *Olearia argophylla* tree (18), *Nematolepis squamea* tree (14), *Pomaderris apetala* tree (19), *Nothofagus cunninghamii* tall shrub (22), *N. squamea* tall shrub (10), *Phyllocladus asplenifolius* tall shrub (15), *P. apetala* tall shrub (20) and *Monotoca glauca* short shrub (14). Two substrates were only in age class c: *Atherosperma moschatum* tree (24) and *Anodopetalum biglandulosum* tall shrub (10). On these substrates, only two species that did not occur in other forest age classes were found. *Radula retroflexa* was only found once on *P. apetala* tall shrub in age class b, and *Diplasolejeunea plicatiloba* was only found once in old growth forest on a tree of *A. moschatum*. Many other species were found only on one substrate type but these substrate types were found in more than one age class (Table 5.3). *Heteroscyphus triacanthus* (age class b) and *Calyptrochaeta brownii, Lejeunea* spp., *Pallavicinia lyelli* and *Sphagnum australe* (all in age class c), only occur in a single age class and on one substrate type (Table 5.3).

Table 5.2. Samples per substrate age class. Number of sites per age class shown in parentheses. '-' = data not available. Only substrate types with 10 or more samples per age class were used in analyses (shown in bold). n/a = not applicable. [a] *Rainforest species defined from (Jarman* et al. *1991) (see Appendix 8.3), Y = rainforest species, ? = doubtful rainforest species, N = non rainforest species.*

Substrate	Rainforest species [a]	Lifeform	Age class		
			a (18)	b (54)	c (33)
Acacia dealbata	?	tree	-	**20**	-
Acacia melanoxylon	?	tree	-	**20**	1
Anopterus glandulosus	Y	tree	-	-	1
Atherosperma moschatum	Y	tree	1	9	**24**
Cenarrhenes nitida	Y	tree	-	-	1
Eucalyptus brookeriana	N	tree	-	1	-
Eucalyptus delegatensis	N	tree	-	**10**	-
Eucalyptus obliqua	N	tree	-	**27**	**23**
Eucalyptus regnans	N	tree	-	**21**	**10**
Eucryphia lucida	Y	tree	-	**10**	**10**
Nematolepis squamea ssp *squamea*	?	tree	-	**14**	9
Nothofagus cunninghamii	Y	tree	1	**22**	**32**
Olearia argophylla	Y	tree	-	**18**	7
Pittosporum bicolor	Y	tree	-	4	2
Pomaderris apetala	?	tree	-	**19**	4
Prostanthera lasianthos	?	tree	-	2	-
Acacia dealbata	?	tall shrub	1	2	-
Acacia melanoxylon	?	tall shrub	-	-	1
Acacia riceana	?	tall shrub	-	3	-
Acacia verticillata	?	tall shrub	-	3	-
Anodopetalum biglandulosum	Y	tall shrub	-	3	**10**
Atherosperma moschatum	Y	tall shrub	-	**10**	**12**
Anopterus glandulosus	Y	tall shrub	-	1	4
Banksia marginata	N	tall shrub	-	1	-
Cassinia aculeata	N	tall shrub	-	1	-
Cenarrhenes. nitida	Y	tall shrub	-	-	3
Coprosma quadrifida	Y	tall shrub	1	5	4
Eucalyptus delegatensis	N	tall shrub	-	2	-
Eucalyptus obliqua	N	tall shrub	1	-	-
Eucalyptus regnans	N	tall shrub	-	3	-
Eucryphia lucida	Y	tall shrub	-	5	5
Hakea lissosperma	N	tall shrub	-	1	-
Leptospermum lanigerum	?	tall shrub	-	-	1
Leptospermum spp.	?	tall shrub	-	2	1
Nematolepis squamea ssp. *squamea*	?	tall shrub	-	**10**	-
Nothofagus cunninghamii	Y	tall shrub	-	**23**	9
Notelaea ligustrina	Y	tall shrub	-	1	1
Phyllocladus asplenifolius	Y	tall shrub	-	**15**	8
Tasmannia lanceolata	Y	tall shrub	-	6	1
Orites diversifolia	Y	tall shrub	-	1	2
Pittosporum bicolor	Y	tall shrub	-	4	2
Pomaderris apetala	?	tall shrub	-	**20**	2
Prostanthera lasianthos	?	tall shrub	-	1	-
Cyathodes glauca	?	short shrub	-	4	2
Cyathodes juniperina	?	short shrub	-	5	-
Leptospermum scoparium	?	short shrub	-	2	-
Melaleuca squarrosa	?	short shrub	-	2	-
Monotoca glauca	Y	short shrub	-	**14**	1
Olearia persoonioides	Y	short shrub	-	-	1
Trochocarpa cunninghamii	Y	short shrub	-	2	-
Trochocarpa disticha	Y	short shrub	-	-	1
Blechnum wattsii	Y	other	-	1	1
Gahnia grandis	Y	other	1	1	-
Dicksonia antarctica (horizontal, dead)	Y	treefern	6	**19**	**13**
Dicksonia antarctica (vertical, dead)	Y	treefern	-	3	3
Dicksonia antarctica (vertical, alive)	Y	treefern	4	**37**	**26**
Log	n/a	n/a	**18**	**54**	**33**
Fallen branch	n/a	n/a	**15**	**54**	**33**
Ground	n/a	n/a	**18**	**54**	**33**
Upturned tree base	n/a	n/a	**10**	**30**	**16**
Stump	n/a	n/a	**17**	**46**	**16**
Roots	n/a	n/a	2	**31**	**27**
Rock	n/a	n/a	**10**	**38**	**22**
Dead tree	n/a	n/a	3	**35**	**19**

Table 5.3. Percentage frequency of species found only on one substrate type.

Substrate type	*Atherosperma moschatum*	*Eucalyptus obliqua*	*Eucalyptus regnans*	*Eucryphia lucida*		*Pomaderris apetala*	*Dicksonia antarctica*		Log		Branch		Stag	Rock		Soil		
Lifeform	Tree	Tree	Tree	Tree		Tall shrub	Treefern											
Age class	c	b	b	b	c	b	b	c	b	c	b	c	b	a	b	a	b	c
N° of samples	24	27	21	10	10	20	37	26	54	33	54	33	35	10	38	18	54	33
Species																		
Brachythecium paradoxum	-	-	-	-	-	-	-	-	-	-	-	-	2.86	-	-	-	-	-
Bryum pseudotriquetrum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.56	-	-
Campylopus clavatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.85	-
Chiloscyphus multipennus aff.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.63	-	-	-
Chiloscyphus rupicolus (Steph.) Engel & Schust	-	-	-	-	-	-	-	-	-	-	1.85	-	-	-	-	-	-	-
Frullania pentapleura	-	-	-	10 00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Grimmia trichophylla	-	-	-	-	-	-	-	-	-	-	-	-	-	10 00	-	-	-	-
Heteroscyphus sp a	-	-	-	-	-	-	-	-	1.85	-	-	-	-	-	-	-	-	-
Kurzia sexfida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.85	-
Orthodontium spp.	-	3.70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plagiochila fuscella	-	-	-	-	-	-	-	-	-	-	1 85	-	-	-	-	-	-	-
Pohlia nutans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2 63	-	-	-
Pohlia sp. a	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.56	-	-
Pyrrhobryum parramattense	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.85	-
Radula retroflexa	-	-	-	-	-	5 00	-	-	-	-	-	-	-	-	-	-	-	-
Rhizogonium pennatum var *aristatum*	-	-	4.76	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Riccardia colensoi	-	-	-	-	-	-	-	-	1 85	-	-	-	-	-	-	-	-	-
Rosulabryum campylothecium (Tayl) Spence	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.56	-	-
Sphagnum falcatulum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5 56	-	-
Heteroscyphus triacanthus	-	-	-	-	-	-	5.41	-	-	-	-	-	-	-	-	-	-	-
Cheilolejeunea albovirens	-	-	-	-	-	-	-	-	-	-	-	3.03	-	-	-	-	-	-
Chiloscyphus bispinosus	-	-	-	-	-	-	-	-	-	-	-	3.03	-	-	-	-	-	-
Diplasiolejeunea plicatiloba	4 17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Frullania monocera	-	-	-	-	-	-	-	-	-	3.03	-	-	-	-	-	-	-	-
Heteroscyphus biciliatus (Hook.f & Tayl) Engel	-	-	-	-	-	-	-	3 85	-	-	-	-	-	-	-	-	-	-
Lepidozia pendulina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.03
Rosulabryum capillare (Hedw.) Spence	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.03
Sematophyllum uncinatum	-	-	-	-	10.00	-	-	-	-	-	-	-	-	-	-	-	-	-
Calyptrochaeta brownii (Dix.) J K. Bartlett	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.06
Lejeunea spp	-	-	-	-	20.00	-	-	-	-	-	-	-	-	-	-	-	-	-
Pallavicinia lyellii (Hook.) Gray	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.06
Sphagnum australe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9 09

A number of species are restricted to a group of like substrate types (Table 5.4 and 5.5). Species found only on coarse woody debris (CWD), CWD and ground and ground and rock are shown in Table 5.4. *Holomitrium perichaetiale* and *Psiloclada clandestina* are only found on coarse woody debris of age class b and c respectively. *Heteroscyphus argutus* was only found on coarse woody debris and soil in ageclass b and *Treubia tasmanica* was only found on rock or soil of age class b. Species that are found only on vascular plants or vascular plants and fallen branches are shown in Table 5.5. In particular, *Paraschistochila pinnatifolia, Drepanolejeunea aucklandica, Chiloscyphus minor, Plagiochila radiculosa, Calyptopogon mnioides, Neckera pennata* and *Daltonia splachnoides* are only found on vascular plants or vascular plants and fallen branches in a single forest age class. Of these species, the first four are found on rainforest vascular plant species and branches in old growth forest. The latter three are found on *Acacia dealbata, Pomaderris apetala* and fallen branches in age class b.

Table 5.4. Percentage frequency of species found only on a group of like substrate types. Substrate type groups include coarse woody debris (CWD; log, fallen branch, upturned root base, stump, dead tree, treefern log), CWD and ground, and ground and rock. Species that had a total occurrence of 1 or that occurred on only one substrate type are not included here (see Table 5.3).

Substrate	*Dicksonia antarctica* horizontal, dead	Log		Fallen branch		Upturned root base		Stump		Dead tree	Rock	Soil		
Age class	b	b	c	b	c	b	c	a	b	b	b	a	b	c
Nº of samples	19	54	33	54	33	30	16	17	46	35	38	18	54	33
Species														
Acrobolbus concinnus	-	-	-	-	3.03	3.33	-	-	-	-	-	-	-	-
Holomitrium perichaetiale	-	-	3.03	-	3.03	-	-	-	-	-	-	-	-	-
Psiloclada clandestina	5.26	-	-	-	-	-	-	-	2.17	-	-	-	-	-
Riccardia eriocaula	-	1.85	3.03	-	-	-	-	-	-	-	-	-	-	-
Ditrichum cylindricarpum	-	-	-	-	-	3.33	6.25	5.88	-	-	-	-	-	-
Chiloscyphus novae-zeelandiae	-	-	3.03	-	9.09	-	-	-	2.17	-	-	-	-	-
Riccardia wattsiana	-	1.85	9.09	-	-	-	-	-	2.17	-	-	-	-	-
Aneura alterniloba	-	3.70	9.09	1.85	-	-	-	-	-	-	-	-	-	-
Heteroscyphus argutus		1.85	-	1.85	-	-	-	-	-	-	-	-	1.85	-
Campylopus purpureocaulis Dusén		1.85	6.06	-	-	6.67	-	-	2.17	-	-	-	-	3.03
Ditrichum difficile		3.70	6.06	-	-	13.33	-	-	2.17	-	-	-	9.26	-
Pallaviciniaceae		1.85	-	-	-	-	-	-	-	-	-	5.56	11.11	18.18
Treubia tasmanica		-	-	-	-	-	-	-	-	-	10.53	-	1.85	-

Table 5.5. Percentage frequency of species found only on a group of like substrate types. Substrate type groups include vascular plants, and vascular plants and fallen branches. Species that had a total occurrence of 1 or that occurred on only one substrate type are not included here (see Table 5.3).

Substrate	*Acacia dealbata*	*Acacia melanoxylon*	*Atherosperma moschatum*	*Eucryphia lucida*	*Nothofagus cunninghamii*	*Nothofagus cunninghamii*	*Olearia argophylla*	*Nematolepis squameum* ssp *squameum*	*Pomaderris apetala*	*Anodopetalum biglandulosum*	*Atherosperma moschatum*	*Nematolepis squameum* ssp *squameum*	*Phyllocladus asplenifolius*	*Pomaderris apelata*	*Monotoca glauca*	Fallen branch		
Lifeform	Tree	Tree	Tree	Tree	Tree	Tree	Tree	Tree	Tree	Tall shrub	Tall shrub	Tall shrub	Tall shrub	Tall shrub	Short shrub			
Age class	b	b	c	c	b	c	b	b	b	c	c	b	b	b	b	a	b	c
N^{o} of samples	20	20	24	10	22	32	18	14	19	10	12	10	15	20	14	15	54	33
Species																		
Paraschistochila pinnatifolia	-	-	4 17	-	-	3.13	-	-	-	10 00	-	-	-	-	-	-	-	-
Radula ratkowskiana	-	-	4 17	-	-	-	5 56	7.14	5 26	10.00	-	-	-	-	-	-	-	-
Frullania aterrima	-	-	4.17	-	9 09	3.13	-	-	-	30 00	-	-	-	-	-	-	-	-
Daltonia splachnoides	-	-	-	-	-	-	-	-	5 26	-	-	-	-	-	-	-	1 85	-
Radula spp.	-	-	-	-	-	-	-	-	-	-	8.33	-	-	-	-	6 67	-	-
Drepanolejeunea aucklandica	-	-	4 17	-	-	-	-	-	-	-	8 33	-	-	-	-	-	-	3 03
Macrocoma tenue ssp *tenue*	-	-	-	-	-	-	-	-	-	-	-	-	-	5 00	-	-	1 85	3 03
Chiloscyphus minor	-	-	4.17	-	-	3 13	-	-	-	10 00	-	-	-	-	-	-	-	3 03
Calyptopogon mnioides	-	-	-	-	-	-	-	-	15 79	-	-	-	-	10.00	-	-	5.56	-
Neckera pennata	10 00	-	-	-	-	-	-	-	15.79	-	-	-	-	10 00	-	-	3 70	-
Plagiochila radiculosa	-	-	12.50	-	-	3 13	-	-	-	10 00	8 33	-	-	-	-	-	-	9 09
Ulota viridis	5 00	10 00	4 17	-	4 55	-	-	-	5 26	-	-	-	-	5 00	-	6 67	1 85	3 03
Metzgeria saccata	5 00	-	12 50	10 00	-	6 25	-	-	-	20.00	25.00	-	6.67	10 00	-	-	1 85	-
Frullania probosciphora	25 00	5 00	4 17	-	-	3 13	11 11	-	26 32	-	-	10 00	-	15 00	7 14	-	3 70	-

Species - substrate association

There were 196 species with expected values less than 5 or not significant for any substrate age class. Many were uncommon, with 27 species recorded only once. The remaining 43 species with at least one significant relationship ($p < 0.05$) are listed in Appendix 8.7. Only three substrate/age classes, *Eucryphia lucida* (tree age class b), *Eucryphia lucida* (tree, age class c) and *Anodopetalum biglandulosum* (tall shrub, age class c), had no significant species significantly associated with them. All remaining substrates had either positive or negative significant species associations, with positive associations listed in Table 5.6. Only positive associations are considered below.

Two bryophyte species preferentially occurred on only one substrate/age class type. Both were in age class 33 – 67 years. *Rhizogonium distichum* was associated with logs and *Balantiopsis diplophylla* occurred preferentially on the ground. Eight species preferentially occurred on two substrate/age class groups. Six of these preferred logs and ground of age class b (*Kurzia hippurioides, Lepidozia laevifolia, L. procera, Rosulabryum billiardieri* var. *billiardieri , Schistochila lehmanniana* and *Kurzia hippurioides* aff.). The other two species preferred old growth forest, *Hypnum cupressiforme* on logs and branches and *Metzgeria decipiens* on branches and roots. Five species preferentially occurred on only three substrate/age class groups (Table 5.6). These were *Cyathophorum bulbosum, Dicranoloma robustum, Gackstroemia weindorferi, Leucobryum candidum* and *Riccardia crassa.*

Twenty-seven of the forty-nine substrate/age classes had preferential species. Of all substrates, logs in age class b had the greatest number of preferential species, with 14 moss and 14 liverwort species. Many of these species were also significant on logs in age class c. Numerous bryophytes that preferentially occurred on fallen branches in age class b, were also associated with logs and ground of the same age class. A similar result was found for fallen branches, logs and ground of old growth. *Eucalyptus obliqua* and *E. regnans* trees in age class b, supported a similar suite of preferential species. The only significantly associated species on young trees of *Nothofagus cunninghamii* was *Warburgiella leucocytus*. It was not significantly associated with older trees. For these older trees, two liverwort species, *Bazzania involuta* and *Chiloscyphus echinellus* and two moss species, *Dicranoloma menziesii* and *Leptotheca gaudichaudii* occurred preferentially. Fallen treeferns in age class b and c do not have

similar associated species. *C. echinellus*, *Cyathophorum bulbosum* and *L. gaudichaudii,* preferentially occur on treeferns in both age classes b and c. *Ptychomnion aciculare* and *Heteroscyphus fissistipus* are both associated with small and large trees of *Pomaderris apetala*. Species, such as *B. involuta, D. menziesii, C. echinellus* and *Leucobryum candidum*, prefer ground in age class c but not age class b. Rocks and ground of age class b have similar associated species

Table 5.6. Substrate age classes and bryophyte species with positive association and significance ($p < 0.05$). Age class (years): a = 1 – 18, b = 33 – 67, c = >110.

Substrate	Lifeform	Age class	p < 0.001	p < 0.01	p < 0.05
Atherosperma moschatum	Tree	c	*Dicranoloma menziesii*		
Eucalyptus obliqua	Tree	b	*Bazzania involuta, Rhizogonium novae-hollandiae, Zoopsis argentea*		
Eucalyptus obliqua	Tree	c	*Bazzania involuta, Rhizogonium novae-hollandiae*		
Eucalyptus regnans	Tree	b	*Rhizogonium novae-hollandiae*	*Zoopsis argentea*	
Eucalyptus regnans	Tree	c			*Bazzania involuta*
Nothofagus cunninghamii	Tree	b			*Warburgiella leucocytus*
Nothofagus cunninghamii	Tree	c	*Bazzania involuta, Chiloscyphus echinellus, Dicranoloma menziesii, Leptotheca gaudichaudii*		
Olearia argophylla	Tree	b	*Ptychomnion aciculare*		
Pomaderris apetala	Tree	b	*Ptychomnion aciculare*	*Heteroscyphus fissistipus*	
Pomaderris apetala	Tall shrub	b	*Heteroscyphus fissistipus, Ptychomnion aciculare*		
Dicksonia antarctica	Horizontal, dead	b	*Heteroscyphus coalitus*		*Leptotheca gaudichaudii*
Dicksonia antarctica	Horizontal, dead	c			*Bazzania involuta*
Dicksonia antarctica	Vertical, alive	b	*Chiloscyphus echinellus, Cyathophorum bulbosum, Leptotheca gaudichaudii*	*Heteroscyphus coalitus*	
Dicksonia antarctica	Vertical, alive	c	*Bazzania involuta, Chiloscyphus echinellus, Cyathophorum bulbosum, Leptotheca gaudichaudii, Rhizogonium novae-hollandiae*	*Dicranoloma menziesii*	
Log	n/a	b	*Achrophyllum dentatum, Bazzania involuta, Chiloscyphus semiteres, Dicranoloma billardieri, Dicranoloma robustum, Dicranoloma robustum* var. *setosum, Gackstroemia weindorferi, Heteroscyphus coalitus, Hypnum chrysogaster, Lepidozia laevifolia, Lepidozia procera, Lepidozia ulothrix, Leptotheca gaudichaudii, Leucobryum candidum, Ptychomnion aciculare, Rhizogonium distichum, Rhizogonium novae-hollandiae, Riccardia crassa, Schistochila lehmanniana, Rhaphidorrhynchium amoenum, Warburgiella leucocytus, Kurzia hippurioides* aff., *Telaranea patentissima, Wijkia extenuata, Zoopsis argentea*		*Heteroscyphus fissistipus, Kurzia hippurioides, Rosulabryum billardieri* var. *billardieri*

Substrate	Lifeform	Age class	p < 0.001	p < 0.01	p < 0.05
Log	n/a	c	*Achrophyllum dentatum, Bazzania involuta, Chiloscyphus echinellus, Dicranoloma billardieri, Dicranoloma menziesii, Gackstroemia weindorferi, Heteroscyphus fissistipus, Hypnum chrysogaster, Lepidozia ulothrix, Leptotheca gaudichaudii, Leucobryum candidum, Ptychomnion aciculare, Rhizogonium novae-hollandiae, Rhaphidorrhynchium amoenum, Telaranea patentissima, Wijkia extenuata, Zoopsis argentea*	*Dicranoloma robustum* var. *setosum, Heteroscyphus coalitus, Hypnum cupressiforme, Warburgiella leucocytus*	*Chiloscyphus semiteres, Cyathophorum bulbosum*
Branch	n/a	b	*Chiloscyphus semiteres, Heteroscyphus coalitus, Lepidozia ulothrix, Riccardia crassa, Rhaphidorrhynchium amoenum, Warburgiella leucocytus, Telaranea patentissima*	*Dicranoloma billardieri, Gackstroemia weindorferi, Heteroscyphus fissistipus, Hypnum chrysogaster, Wijkia extenuata*	*Dicranoloma robustum, Ptychomnion aciculare, Thuidium sparsum*
Branch	n/a	c	*Bazzania involuta, Dicranoloma menziesii, Hypnum chrysogaster, Hypnum cupressiforme, Lepidozia ulothrix, Warburgiella leucocytus, Telaranea patentissima*	*Chiloscyphus echinellus, Heteroscyphus coalitus, Ptychomnion aciculare, Rhaphidorrhynchium amoenum, Wijkia extenuata*	*Achrophyllum dentatum, Dicranoloma robustum* var. *setosum, Metzgeria decipiens*
Soil	n/a	b	*Achrophyllum dentatum, Balantiopsis diplophylla, Dicranoloma billardieri, Dicranoloma robustum, Heteroscyphus coalitus, Heteroscyphus fissistipus, Lepidozia procera, Ptychomnion aciculare, Rosulabryum billardieri* var. *billardieri, Schistochila lehmanniana, Kurzia hippurioides* aff., *Telaranea patentissima, Thuidium sparsum, Wijkia extenuata, Zoopsis argentea*	*Hypnum chrysogaster, Kurzia hippurioides, Lepidozia laevifolia, Lepidozia ulothrix, Rhizogonium novae-hollandiae, Riccardia crassa*	*Chiloscyphus semiteres, Rhaphidorrhynchium amoenum*
Soil	n/a	c	*Achrophyllum dentatum, Bazzania involuta, Dicranoloma menziesii, Heteroscyphus coalitus, Heteroscyphus fissistipus, Leucobryum candidum, Ptychomnion aciculare, Rhizogonium novae-hollandiae, Telaranea patentissima, Zoopsis argentea*	*Chiloscyphus echinellus, Lepidozia ulothrix, Wijkia extenuata*	*Dicranoloma billardieri, Hypnum chrysogaster*
Stump	n/a	b	*Dicranoloma robustum* var. *setosum, Rhizogonium novae-hollandiae*	*Lepidozia ulothrix, Leptotheca gaudichaudii*	*Bazzania involuta*
Stump	n/a	c		*Bazzania involuta, Rhizogonium novae-hollandiae*	*Lepidozia ulothrix*
Roots	n/a	b			*Heteroscyphus coalitus*

Substrate	Lifeform	Age class	p < 0.001	p < 0.01	p < 0.05
Roots	n/a	c	*Bazzania involuta, Chiloscyphus echinellus, Dicranoloma menziesii, Lepidozia ulothrix*	*Heteroscyphus coalitus, Wijkia extenuata*	*Hypnum chrysogaster, Metzgeria decipiens, Ptychomnion aciculare*
Rock	n/a	b	*Heteroscyphus coalitus*	*Heteroscyphus fissistipus, Wijkia extenuata, Rhaphidorrhynchium amoenum*	*Ptychomnion aciculare*
Rock	n/a	c		*Heteroscyphus fissistipus*	
Stag	n/a	c			*Bazzania involuta*

Substrate species composition

The NMDS ordination of environmental variables shows points clustered into approximately 3 groups, with only one of these not containing sites from each age class (Figure 5.1, stress = 0.1374). ANOSIM demonstrates there is no significant difference in environment characteristics between age class groups (age class a and b: R = 0.0188, p = 0.2190; age class a and c: R = -0.0062, p = 0.4800; age class b and c: R = 0.0286, p = 0.0850).

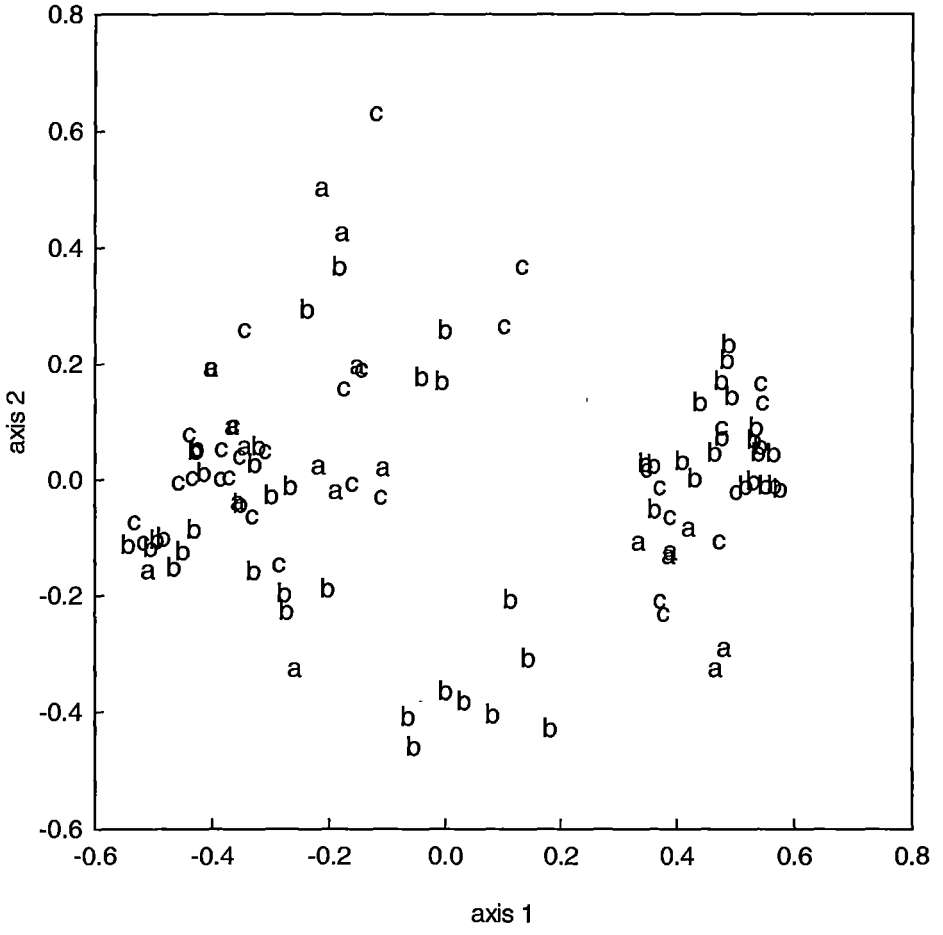


Figure 5.1. NMDS ordination of environmental variables of 105 sites labelled by age class: a = age class a; b = age class b; c = age class c. Variables include altitude, aspect, slope, mean annual rainfall, rainfall of the driest month, mean annual temperature and latitude.

Differences in species composition between the 49 substrate age class groups were apparent ($R = 0.4982$ $p < 0.001$). Many pairwise comparisons between substrate/age classes were highly significant ($p < 0.001$) (Appendix 8.8). Numerous substrates from age class a are similar in species composition to other substrates of the same age class and significantly different from substrates of age class b and c (all pairwise comparisons $p < 0.001$) (Figure 5.2 and 5.3). Of the substrates from age class b and c, a large number had species compositions that were significantly dissimilar to all other substrate/age class groups. These included: *Nothofagus cunninghamii* trees (old growth), *Atherosperma moschatum* trees (old growth), treeferns (old growth); *Monotoca glauca* tall shrubs (age class b); logs; fallen branches and ground (age class b and c); roots (old growth); and rocks (age class b).

The bryophyte species composition on rough and smooth bark vascular species was significantly different ($R = 0.2501$ $p < 0.001$) (Figure 5.3). Bryophyte species composition on different *Eucalyptus* species was not similar, with differences for the same tree species also detected across age class. The species composition of *E. regnans* trees in age class b was similar to the species composition of dead trees, stumps and *E. delegatensis* trees of the same age but weakly dissimilar to *E. regnans* trees in old growth ($R = 0.2641$ $p = 0.003$). *E. obliqua* trees of age class b had a species composition similar to *E. regnans* trees in old growth (Figure 5.3), although low but significant R values were detected with other *Eucalyptus* spp. (Figure 5.2) (pairwise comparisons, *E. obliqua* tree age class c, $R = 0.077$, $p = 0.01$, *E. regnans* tree age class b, $R = 0.0774$, $p = 0.021$). Species compositions of old growth *Nothofagus cunninghamii* and *Atherosperma moschatum* trees were significantly different to many other substrate age class groups ($p < 0.001$). *A. moschatum* trees were different in species composition between age classes b and c. Weak dissimilarities in species composition were found between age class b and old growth *N. cunninghamii* trees ($R = 0.1788$, $p < 0.001$) and age class b tall shrubs and old growth trees of *A. moschatum* ($R = 0.1868$, $p < 0.011$). Of the more smooth bark substrates, for age class b, the species compositions of *Nematolepis squamea* trees and tall shrubs were similar, likewise for *Pomaderris apetala* tree and tall shrub (Figure 5.3). No similarity in species composition was found between these two vascular species (Figure 5.3). Weak significant dissimilarity was found between *P. apetala* of age class b and two other substrates, *Acacia dealbata* tree and *Olearia argophylla* tree, both of age class b

(pairwise comparisons with *A. dealbata*; *P. apetala* tree R = 0.0823, p = 0.011, *P. apetala* tall shrub R = 0.0876, p = 0.012, pairwise comparisons with *O. argophylla*; *P. apetala* tree R = 0.0813, p = 0.011, *P. apetala* tall shrub R = 0.0566, p = 0.045). *A. moschatum* tall shrubs were of similar species composition in age class b and c. The species composition of *N. cunninghamii* trees and tall shrubs for age class b were similar (R = 0.0589, p = 0.044).

Dead tree species composition was similar in age classes b and c. It was likewise for stumps, upturned root bases and treefern logs. Treeferns in old growth were weakly dissimilar in species composition with three substrate age classes: *Nothofagus cunninghamii* trees in old growth (R = 0.1933, p < 0.001), old growth stumps (R = 0.1813 p < 0.001) and treeferns in age class b (R = 0.0549, p = 0.048). The species composition of logs of age class b and c were weakly dissimilar (R = 0.1698, p < 0.001). Weak dissimilarity in species composition was also found between logs and branches in age class b (R = 0.2196, p < 0.001) and logs and branches in old growth (R = 0.238, p < 0.001). Branch species composition was weakly dissimilar between age classes b and c (R = 0.2009, p < 0.001). Ground species composition is significantly different to many other substrate age class groups. However weak dissimilarity was found between ground and logs of age class b and c (pairwise comparison: age class b, R = 0.1825 p < 0.001, age class c, R = 0.1928 p < 0.001).

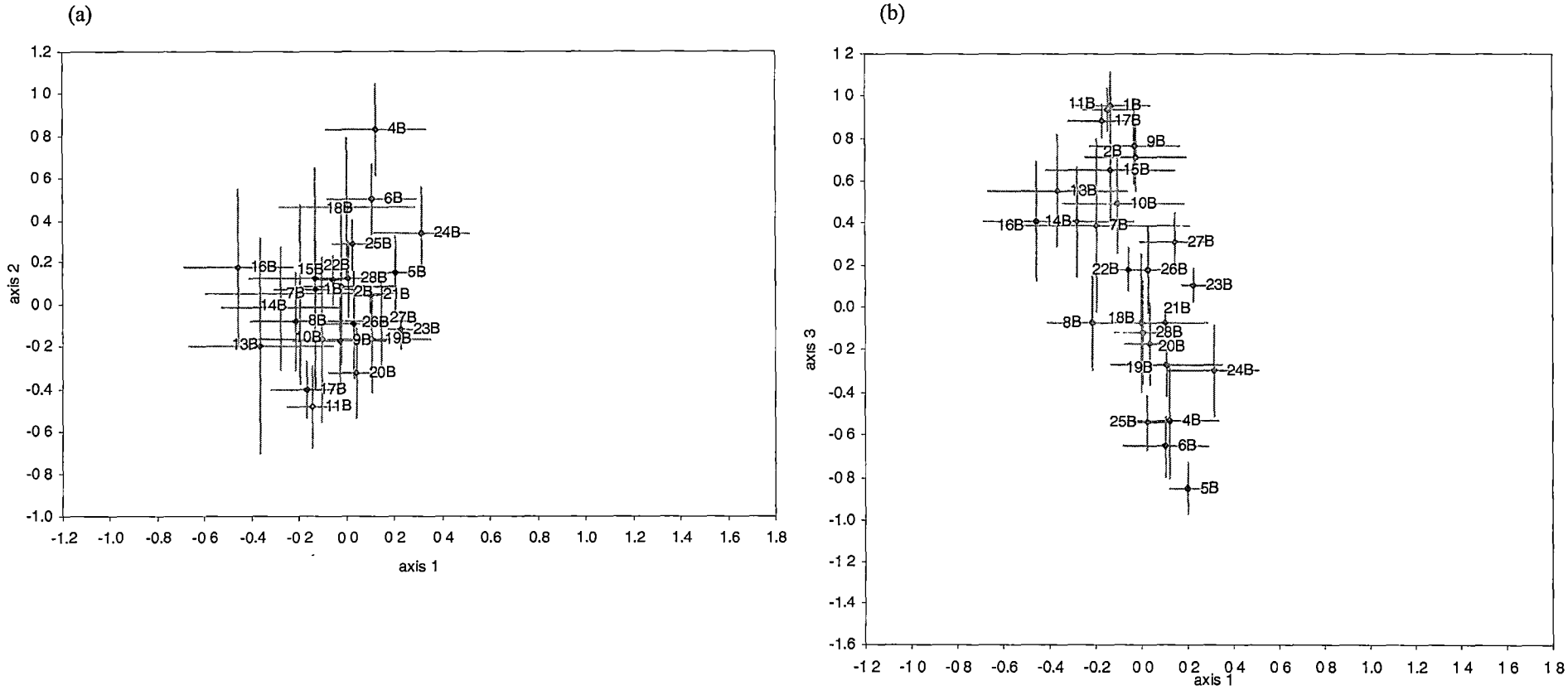
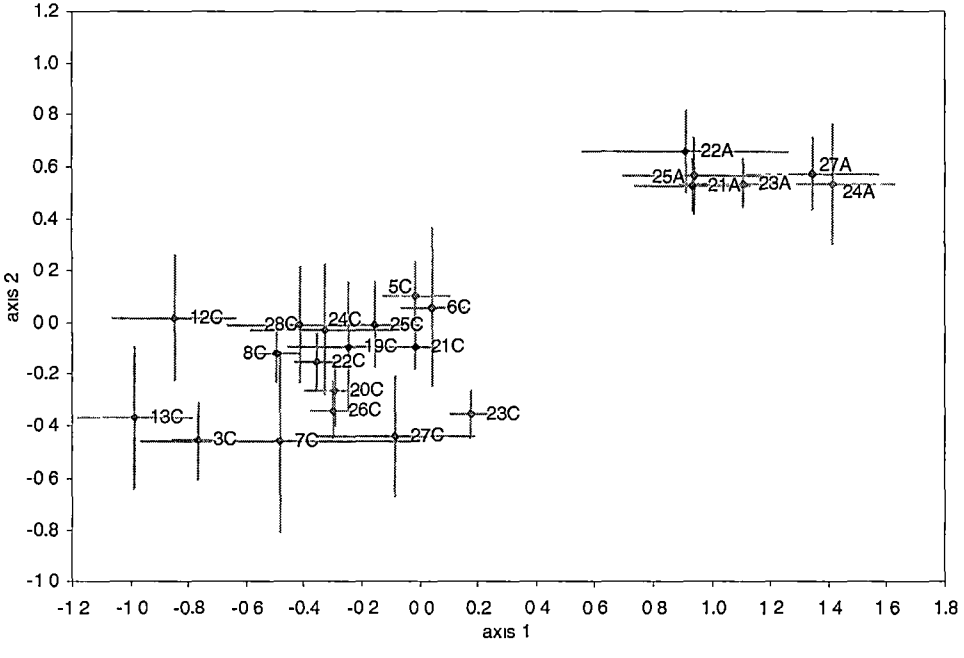
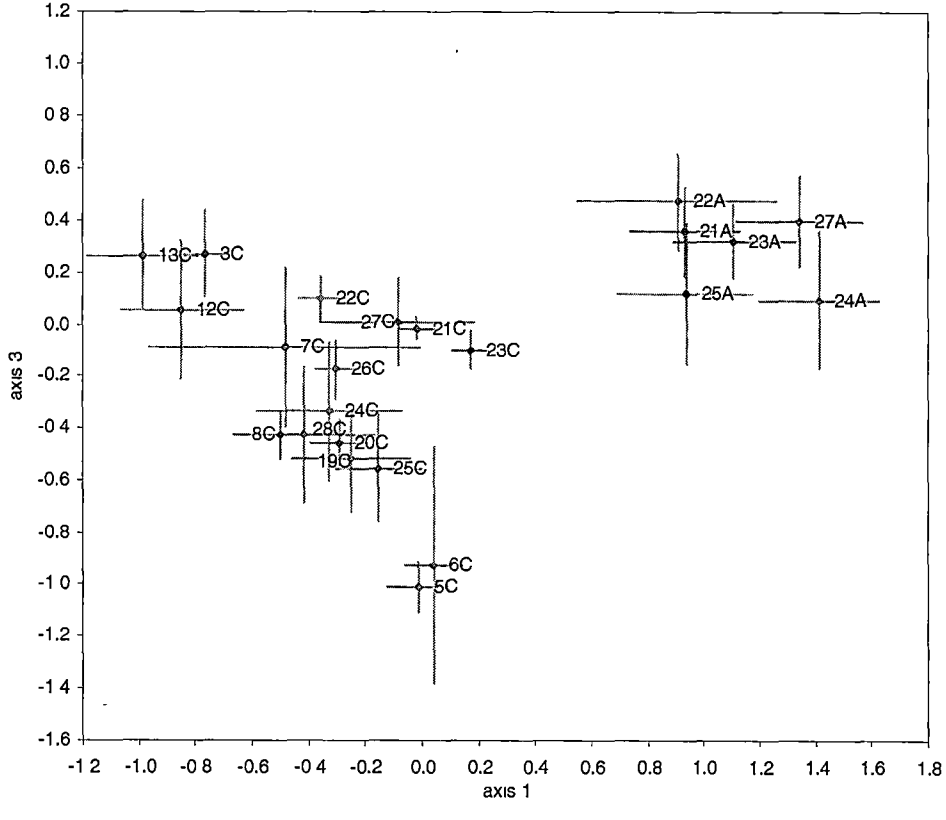


Figure 5.2. Three dimensional ordination of mean of ordination scores and 95% CI for each substrate by age class. For ease of portrayal, substrates in the ordination are shown in separate figures; (a - b) shows substrates in age class B, (c - d) substrates in age classes A and C. Numbers indicate substrate type: 1 - 11 = trees, 12 – 17 = tall shrubs, 18 = short shrub. 1 = Acacia dealbata, *2* = A. melanoxylon, *3* = Atherosperma moschatum, *4* = Eucalyptus delegatensis, *5* = E. obliqua, *6* = E. regnans, *7* = Eucryphia lucida, *8* = Nothofagus cunninghamii, *9* = Olearia argophylla, *10* = Nematolepis squamea *ssp.* squamea, *11* = Pomaderris apetala, *12* = Anodopetalum biglandulosum, *13* = Atherosperma moschatum, *14* = N. cunninghamii, *15* = N. squamea *ssp.* squamea, *16* = Phyllocladus asplenifolius, *17 = P. apetala, 18* = Monotoca glauca, , *19* = Dicksonia antarctica *(horizontal, dead), 20* = D. antarctica *(vertical, alive), 21 = log, 22 = fallen branch, 23 = soil, 24 = upturned root base, 25 = stump, 26 = roots 27 = rock 28 = dead tree. Minimum stress = 0.2274.*

(c)


axis 2
axis 1
22A
25A
21A
23A
27A
24A
5C
6C
12C
28C
24C
25C
8C
19C
21C
22C
20C
26C
13C
23C
3C
7C
27C

(d)


axis 3
axis 1
22A
21A
27A
23A
25A
24A
13C
3C
12C
22C
27C
21C
23C
7C
26C
24C
8C
28C
20C
19C
25C
6C
5C

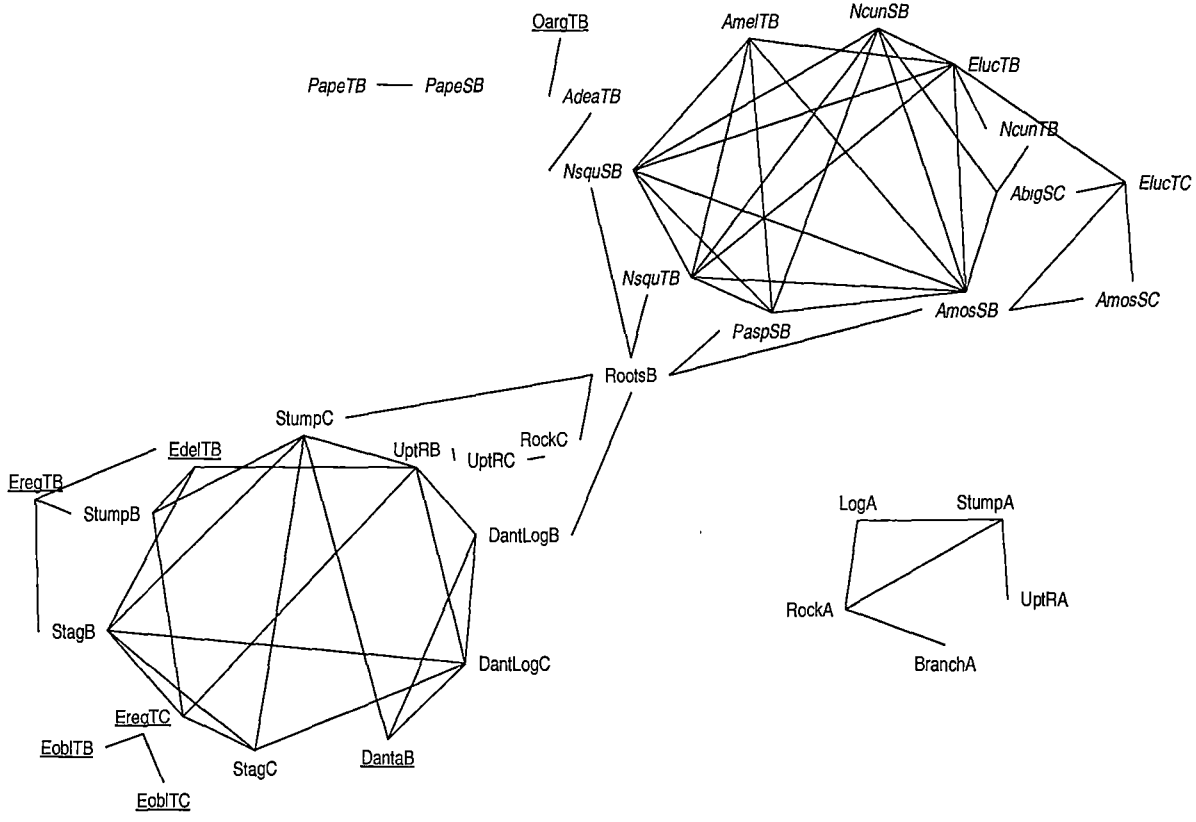


Figure 5.3. Substrate age classes with pairwise comparisons from ANOSIM with significance p = > 0.05. Lines are not to scale but simply indicate no significant difference. Abbreviations: A, B and C are age classes a, b and c respectively; Abbreviations: Adea = Acacia dealbata, *Amel* = A. melanoxylon, *Abig* = Anodopetalum biglandulosum, *Amos* = Atherosperma moschatum, *Branch = fallen branch, Danta* = Dicksonia antarctica *(vertical, alive), DantLog* = D. antarctica *(horizontal, dead), Ereg* = Eucalyptus regnans, *Eobl* = E. obliqua, *Edel* = E. delegatensis, *Eluc* = Eucryphia lucida, *Log = log, Ncun* = Nothofagus cunninghamii, *Oarg* = Olearia argophylla, *Pape* = Pomaderris *apetala, Nsqu* = Nematolepis squamea *ssp.* squamea, *Rock = rock, S = tall shrub, Stag = dead tree, Stump = stump, T = tree, UptR = upturned root base, Roots = roots. Abbreviations in italics are smooth barked species whereas those underlined are rough barked species.*

Discussion

Of the twelve substrates found only in one forest age class, only two had species that did not occur in any other forest age class. *Diplasolejeunea plicatiloba* has been listed as reserved in different locations around the state (Moscal and Kirkpatrick 1997). *Radula retroflexa* was only found once on a small *Pomaderris apetala* tree in age class b; a site that had been clear fell logged in 1963. Both the site and surrounding vegetation are currently managed under Tasmania's state forest system and are subject to logging and plantation practices. *R. retroflexa* is a little known species; there are no previous documented records (Moscal and Kirkpatrick 1997), but there have been personal observations (J. Jarman pers comm. 2003). More information concerning its distribution and abundance is needed before any conclusions regarding vulnerability to extinction can be made.

Many bryophyte species were only found within one age class, with a number of species found on only one substrate type or a group of like substrate types. The liverwort species, *Paraschistochila pinnatifolia, Drepanolejeunea aucklandica, Chiloscyphus minor and Plagiochila radiculosa,* were only found on rainforest vascular plant species in old growth forest. *Pomaderris apetala* trees were found in age class b (> 10 samples) and age class c (< 10 samples). *Acacia dealbata* trees were found only in age class b. Both of these tree species in age class b were significant substrates for two moss species, *Neckera pennata* and *Calyptopogon mnioides*. Conservation of forests of different age classes may be required for the presence of these bryophyte species.

Of the substrate age classes sampled in mixed forest, many had significantly associated species and distinct assemblages of bryophytes. Species significantly associated with only a single substrate age class in this study have been reported as indicative of the same substrate elsewhere, in similar aged forest (Ashton 1986; Jarman and Kantvilas 2001b). Few bryophyte species were specific to a particular substrate age class type. Most bryophytes appear well adapted to occupy a variety of substrates and tolerate variation in substrate quantity and quality (Kruys and Jonsson 1999), and climatic conditions (Söderström 1981).

Eucalyptus obliqua and *E. regnans* of age class b (33 – 67 years) had similar associated species and species compositions, as observed in previous studies (Ashton 1986; Jarman

and Kantvilas 2001b). *E. regnans* trees in age class b forest had a slightly different bryophyte species composition to *E. regnans* in old growth. Differences in bark properties, such as the water holding capacity of the bark of young and old *E. regnans* trees may explain the differences in species composition. Difference in epiphyte species composition has been associated with differing bark type, with thicker bark and increased shading assisting in the greater retention of water (Billings and Drew 1938). As *E. regnans* grows, buttresses form, creating microhabitats not present in younger trees. Deep crevices provide shade and divert water flow. Mature basal bark of *E. regnans* has a water holding capacity of 280-330% (oven dry-weight), much greater than thin barked trees such as *Pomaderris aspera* (like *P. apetala*; water-holding capacity 164% oven dry weight) (Ashton 1986). The creation of new microhabitats and increased water retention in *E. regnans* trees of old growth forest may enable a suite of bryophyte species, not present on trees of intermediate regrowth forest, to establish.

N. cunninghamii tall shrubs and trees in age class b forest were similar in species composition. The species composition of *N. cunninghamii* trees in age class b and c was weakly dissimilar. A successional sequence in age/size of the tree and bark type may account for these results. All tall shrubs and trees of *N. cunninghamii* in age class b forest have smooth bark. They are subject to comparable climatic conditions thus species composition is similar. Within old growth forest, the majority of *N. cunninghamii* trees are old and larger than age class b trees and the bark is more firm, and coarse. In old growth forest, few younger, smooth bark trees are present. Bark characteristics and age of *N. cunninghamii* trees between ageclasses b and c may explain the differences in species composition observed. This is consistent with the results of a previous study on *N. cunninghamii*, which found a relationship between the size of the trunk and diversity of the bryophyte composition present (Ashton and McCrae 1970).

For *Atherosperma moschatum*, trees and tall shrubs in old growth forest have a weakly dissimilar species composition. These results are similar to the only other Australian study to look at bryophyte species on *A. moschatum* of differing sizes (Ashton 1986). Ashton (1986) found qualitative evidence for young *A. moschatum* trees supporting species also found in the uppermost crowns of larger, older trees. Bark texture of *A. moschatum* remains smooth with increasing age of the tree. In a study of tree species in

forest of eastern North America, a similar result to the present study was found; tree species that showed no change in bark properties with age, showed no great change in epiphytes with age (Slack 1976).

Previous Australian studies have described the bryophyte species composition of vascular plants by combining vascular species of similar bark into bark type groups and describing the bryophyte species composition of these groups (Ashton 1986; Jarman and Kantvilas 2001b). The present study, like these previous studies, found the species composition of bryophytes was significantly different between smooth and rough bark vascular species groups. However, 'rough' barked *Olearia argophylla* had a bryophyte species composition similar to 'smooth' barked *Acacia dealbata*. Within bark type, bryophyte species composition differed between some vascular species, as was the case between the smooth bark vascular species *Pomaderris apetala* and *Nematolepis squamea*. Other studies have found bark pH, bark chemistry and soil chemistry to affect bryophyte composition (Bates 1992; Gustafsson and Eriksson 1995). Thus, bark type may be just one of a number of factors that influence the bryophyte composition of different vascular species in mixed forest.

Bryophytes on treeferns are not restricted to a particular substrate type or age class; treeferns in age class b and old growth forest have similar species compositions. Although some species, such as *Leptotheca gaudichaudii*, are significantly associated with treeferns, they also occur preferentially on other substrates. The trunks of treeferns are made up of a mass of roots with the only structural change over time being the growth of roots over the trunk surface. The lack of difference in environmental characteristics between age classes b and c may explain the similarity in species composition between treeferns of age class b and old growth forest and lack of specific species found on treeferns. These results are similar to those of a study on treeferns in New Zealand that concluded that a wide substrate range for a species indicated a preference for a particular environmental setting rather than a type of substrate (Beever 1984).

Of all substrates, logs in forest of age class b had the greatest number of significantly associated species with many of these species also associated with old growth forest logs. The species composition of logs in age class b and old growth forest was weakly dissimilar. This is in contrast with other studies where differences in species

compositions were found, despite no difference in amount of decaying wood between unmanaged and managed stands (Söderström 1988a; Spies *et al.* 1988; Rambo and Muir 1998b). Although no decay stages of logs in age class b forest or old growth forest were recorded in this study, logs of the former age class exhibit various levels of decay (Ashton 1986; Jarman and Kantvilas 2001b) and there is a large volume of coarse woody debris available for colonisation (~ 400 – 1200 m^3 ha^{-1} Forestry Tasmania unpublished data; see also Meggs 1997; McKenny and Kirkpatrick 1999). Lindenmayer *et al.* (1999) recorded log volumes of averaging 350 m^3 ha^{-1} with 1000 m^3 ha^{-1} for some sites. In addition volumes did not differ significantly between young, mature and old growth stand ages. Wood rotting fungi and the existence of a large invertebrate flora assist in the rapid breakdown of coarse woody debris (Ashton 1986). The forests sampled in the present study have not been heavily managed, with only one disturbance event assumed. Sites burnt by wildfire may lack the large logs of old growth forests, but falling dead trees maintain continuity, adding woody debris to the forest. Elsewhere, clearfell logged forests after ~40 years still had the presence of pre-logging coarse woody debris (Sturtevant *et al.* 1997). In comparison, Swedish forests are heavily managed and coarse woody debris ranges in volume with managed stand having amounts such as of 2.2 m^3 ha^{-1} (Kruys *et al.* 1999) and 65.48 m^2 ha^{-1} (Söderström 1988a) while examples of old growth forests have 197 m^3 ha^{-1} (Linder *et al.* 1997) and 72.24 m^2 ha^{-1} (Söderström 1988a). Log volume is slightly higher in forests of western Oregon and Washington, however young and mature stands of two or more widely separated age classes of trees were avoided (40-80yrs 248 m^3 ha^{-1}, 80-200 years 148 m^3 ha^{-1}, >200 years 313 m^3 ha^{-1}, (Spies *et al.* 1988). A lack of available substrate could restrict the establishment of some bryophyte species. An abundance of available woody substrate in wet eucalypt forest and less management may explain why bryophyte species composition on logs of intermediate forests is similar to that found for old growth forests.

Resemblance in species composition was found between logs and ground in 33 – 67 year forest and between logs and ground in old growth forest. Similar species compositions were also found between branches and ground and logs of 33 – 67 year forest and branches and logs of old growth. Close proximity of woody substrates to the ground, the build up of humus on and around woody substrates and colonisation of wood from the sides or the upper surface have all been suggested as possible reasons for

finding epixylic species growing on the ground and terricolous species on wood (Muhle and LeBlanc 1975; Söderström 1988a; Rambo and Muir 1998a; Qian *et al.* 1999).

Overall, many bryophyte species in wet eucalypt forest were found only on a particular substrate or like substrate types. In particular, logs are an important substrate in these forests, fostering a large suite of bryophyte species. Although many bryophyte species found on logs exist on other substrates, a loss of logs from the landscape may negatively affect the persistence of some species. The present study questioned whether there are differences in bryophyte species composition between some substrates in similar aged forest. This was found between some substrates, emphasising that the existence of a variety of substrate types in the landscape is likely to be necessary to maintain the high level of bryophyte diversity found in the present study.

Chapter Six

A comparison of bryophytes and vascular plants in wet eucalypt forest regeneration after clear-felling and wildfire

Abstract

There is much debate regarding the impacts on biodiversity of clearfell logging and its its effects compared to wildfire in the wet eucalypt forest of Australia. Bryophytes are a major component of biodiversity in wet eucalypt forests. The composition of bryophyte and vascular species was investigated at 50 sites in Tasmanian mixed forest in three latitudinal bands (Southern, Northern and Central), some of which had been burned in wildfires and the rest of which were clearfelled and burnt by prescribed fires. Site characteristics (cover of substrates and basal area of vascular species) were also recorded. A total of 204 bryophyte taxa and 98 vascular plant taxa were recorded from the 50 sites. For bryophytes, this included 95 moss and 109 liverwort species. This constitutes approximately one third of the total bryophyte flora for Tasmania. Four moss species occurred more frequently in logging than wildfire regeneration, whereas of the seven bryophytes species that occurred more frequently in wildfire than logged forest, six were liverworts. Of three vascular species found more commonly in wildfire than logging regeneration, one was an epiphytic fern. For all sites (n = 50), there was little difference between logging and wildfire regeneration for vascular and bryophyte species composition. Significant differences in % cover of substrates were found for rock, dead tree and total above ground substrate cover, with all cover values greater in wildfire sites than logging sites. The basal area of dead trees was also significantly higher in wildfire than clearfell forest whereas the opposite was true for the basal area of Nothofagus cunninghamii *and total basal area of vascular plants. When sites were separated into latitudinal bands, bryophyte species composition differed between logging and wildfire only in the Central forest. In addition, there was a higher percentage cover of dead trees, rocks and above ground substrates, in wildfire than clearfell sites. Substrates such as logs, dead trees, and different vascular species are all key components in maintaining diversity of bryophytes species in mixed forest. Given the cover of substrates is significantly less in clearfell logged forest than wildfire forest, and bryophytes appear to be slow colonisers compared to their vascular counterparts, a*

second rotation event may negatively impact on recolonisation of bryophytes into a clearfelled forest.

Introduction

In many forest ecosystems, wildfire initiates regeneration (Ashton 1981b; Hansen *et al.* 1991; Attiwill 1994a; Lindenmayer *et al.* 2000). Fire may stimulate plant growth, provide habitats for wildlife, in the forms of dead trees and logs, and create a mosaic of forest ages in the landscape (Ashton 1981b; Lindenmayer *et al.* 1991; Shea *et al.* 1993; Lindenmayer *et al.* 2000). Depending on the intensity of a fire, bryophytes (mosses and liverworts) of forests are either completely destroyed and new colonisers invade, or pre and post-disturbance species flourish (Warcup 1981; Ashton 1986). After fire, bryophytes form a mat on the soil surface and assist (by moisture retention) or inhibit (by competition) vascular plant recolonisation (Duncan and Dalton 1982; Hill and Read 1984). Natural disturbance is defined here as a process in which humans do not have a considerable participation and which interrupts function and structure of an environment. Timber harvesting, followed by a regeneration burn, is one of the main disturbance types caused by humans in forests (Hansen *et al.* 1991; Attiwill 1994a). Silvicultural practices alter the forest composition and structure in many different ways. For example trees are removed, soil is compacted, and regeneration burns are more uniform and of higher intensity than natural burns (Ough 2001). Two questions regarding silvicultural practices are whether they imitate natural ecological processes and is biodiversity negatively affected (Hansen *et al.* 1991; Attiwill 1994a; Brown 1996; Lindenmayer *et al.* 2000).

Tasmanian mixed forest is defined as vegetation with a rainforest understorey and eucalypt overstorey (Gilbert 1959). The term 'wet eucalypt forest' includes both mixed forest and forests with broad-leaved shrubs and/or ferns dominant in the understorey (Kirkpatrick *et al.* 1988). About 27% of wet eucalypt forest is reserved in Tasmania, with approximately 57% available for timber harvesting (Resource Planning and Development Commission 2002). It is estimated that 29% of wet eucalypt forest in Tasmania is old growth, with 64% existing in reserves (Resource Planning and Development Commission 2002). Mixed forest is defined as vegetation with a rainforest understorey and eucalypt overstorey (Gilbert 1959). Fires maintain mixed forest at intervals of 100 - 400 years (Gilbert 1959; Jackson 1968; Mount 1979; Hickey

1994). The older stands of mixed forest are termed 'old growth forest' and have great aesthetic and natural significance. However, if there is an absence of fire for more than approximately 400 years, the eucalypts of old growth forests die out, leaving rainforest (Jackson, 1968). Mixed forests have a high wood production value. They are harvested for the production of sawlogs (*Eucalyptus* spp.), pulpwood and speciality wood products (rainforest species). Clear fell and burn harvesting has been extensively practiced in Tasmania since the 1960's. It is currently the most commonly used method (Forestry Tasmania 1998). Clearfell and burn harvesting involves completely clearing all trees in an area of usually less than 100 ha (Forest Practices Board 2000) in a single operation (Gilbert and Cunningham 1972). The remaining litter (slash, unsaleable timber, remnant understorey etc.) is burnt to create a seedbed in which regeneration of both overstorey and understorey vascular plants can occur. Revegetation of *Eucalyptus* is today mostly undertaken by aerial sowing of seed (Forestry Tasmania 1998). Other methods used in the past and less commonly today include hand seeding/sowing and natural seeding. Where natural seeding is used, seed is supplied by retained and/or surrounding mature trees (Gilbert and Cunningham 1972; Florence 1996). For instance, in the 1960's and 1970's, seed supply was partly achieved by retaining < 20 eucalypt trees per hectare (Florence 1996). The planned interval between logging events for wet eucalypt forests including mixed forest is 90 years (Whiteley 1999).

Not surprisingly, comparisons of older forest and younger logged stands show differences in bryophytes and/or vascular species diversity and species composition (Lesica *et al.* 1991; Mueck and Peacock 1992; Ough and Ross 1992; Hickey 1993; Carleton and MacLellan 1994; Jarman and Kantvilas 1997; Vellak and Paal 1999). Carleton and MacLennan (1994) found differences in vascular species composition between young logged forests with a mean age of 23 years and older forests burnt by wildfire with a mean age of 90 years. Lesica *et al.* (1991) suggested a difference in bryophyte species composition between old and managed stands was a consequence of liverworts and older trees found only in older stands. The effects of age and disturbance confound comparisons of species composition and structure in these forests; a more appropriate contrast to the effects of logging on biodiversity is the effect of natural disturbance such as wildfire, controlling for environment and stand age (Roberts and Gilliam 1995). If logging is to be used as a surrogate for natural disturbance (Attiwill 1994b) then verification of its suitability is required.

The only research concerning bryophytes in disturbed mixed forest has focused on clearfell burning effects on bryophyte nutrient content, bryophyte regeneration and soil chemistry (Duncan and Dalton 1982; Brasell and Mattay 1984; Brasell *et al.* 1986). The effects of clearfelling compared to wildfire on bryophytes in mixed forest of similar age are largely unknown. Two studies have compared vascular plant floristics in clearfell logging and wildfire wet eucalypt forests of similar ages: Ough (2001) in ~ 20 year old Victorian *Eucalyptus regnans* forest; and Hickey (1994) in *E. regnans* and *E. obliq*ua dominated mixed forest aged ~ 20 – 30 years in Tasmania. Despite the similar eucalypt dominants, the forest communities surveyed in each study were different (Kirkpatrick *et al.* 1988). Ough (2001) found a significant difference in floristics between clearfell logging and wildfire forest. Hickey (1994) found that after a single logging event, vascular plant floristics of logged forest were similar to that of wildfire forests. Given that the standard rotation length for regrowth forest logging in Tasmania is 80 – 100 years, Hickey (1994) stated that it was unknown if epiphytic ferns would recover within the first rotation of logging. He indicated the effects on filmy ferns might be representative of the possible effects on bryophytes and lichens.

Comparative studies in boreal forest have reported differences in bryophyte species composition following wildfire or clearcut logging (Johnston and Elliot 1996; Nguyen-Xuan *et al.* 2000). Nguyen-Xuan e*t al.* (2000) found differences in species composition (bryophytes, lichens and vascular plants) between wildfire and logging in very young (< 5 years) and young (< 10 – 15 years) stands in Quebec. Differences were probably due to an increase in pioneer species after fire and an increase in residual species after logging. Conversely, in northern Minnesota, Reich *et al.* (2001) found no difference in bryophyte or vascular plant species composition between clearcut logging and wildfire stands of two age classes (25 – 40 and 70 – 100 years). The clearcut areas in the studies of Nguyen-Xuan e*t al.* (2000) and Reich *et al.* (2001) were not burnt post –logging. Where prescribed burning has been used as a post-harvest method in boreal forest and comparisons to wildfire regeneration made, differences were found in the species composition of herbaceous plants (vascular and non-vascular) (Johnston and Elliot 1996). Comparisons between clearfell-burn (eg. Hickey 1994) and clearcut–no burn logging (eg. Nguyen-Xuan e*t al.* 2000; Reich *et al.* 2001) are made difficult as, in contrast to eucalypt forest, boreal forest is logged mostly in winter on snow to decrease soil disturbance.

This study is the first to investigate the effect of clearfell logging and wildfire on wet eucalypt forest bryophytes. In particular the following questions are addressed: (1) are the proportion of sites with each bryophyte and vascular species the same for each disturbance type? (2) does species composition of bryophytes and vascular plants differ between disturbance types and if so (3) what environmental variables explain the variation in species composition between forest types?

Materials and Methods

Site selection

Data were collected from 50 sites (Figure 6.1). Forty-four of these sites (22 logged and 22 wildfire) were sampled earlier by Hickey (1994) in a vascular plant study, which also incorporated sites from data collected by Satwant Calais in 1976/77. These original 44 sites were not permanently marked but were approximately relocated using grid references. The selection of all sites and additional sites, were from Forestry Tasmania photo interpretation maps and areas classified before disturbance as old growth mixed forest with a eucalypt height potential of 41 m. All sites were below 700 m and only one disturbance; either clearfell-burn logging or wildfire was evident.

Sites fall into three latitudinal bands. These latitudinal bands are defined by, geographic separation, eucalypt dominance, vascular species composition and geology. Sites in the northern latitudes of the state (Arthur River forests, Northern forest) were dominated by *Eucalyptus obliqua* and *E. brookeriana*. Mean annual temperature ranges from 10.5 to 12.1 °C (average 11.62 ± 0.14 °C) and mean annual rainfall is from 1347 to 1888 mm (average 1495.53 ± 47.68 mm). The geology is principally siliceous including, siltstone and mudstone, with some areas on the argillaceous rock, basalt. In the forest of central latitudes (Styx and Florentine River valleys, Central forest) *E. regnans* was dominant with occasional *E. obliqua* as co-dominant. Mean annual temperature ranges from 7.5 to 8.6 °C (average 8.32 ± 0.09 °C) and mean annual rainfall is from 1486 to 1615 mm (average 1573.11 ± 12.97 mm). The geology of this area is predominantly siliceous rocks (mudstone and siltstone) with limestone also. The southern latitude forests (Arve, Picton and Weld River, Southern forest) were dominated by *E. obliqua* with *E. delegatensis* or *E. regnans* sometimes co-dominating. Mean annual temperature ranges from 8.6 to 10.6 °C (average 9.62 ± 0.21 °C) and mean annual rainfall is from 1147 to

1534 mm (average 1325.94 ± 43.57 mm). The geology of the southern forests is mainly igneous (dolerite). Over all sites, mean annual temperature ranges from 7.5 to 12.1 °C (average 9.76 ± 0.2 °C) and mean annual rainfall is from 1147 to 1888 mm (average 1465.80 ± 25.54 mm). Site characteristics by forest disturbance type are given in Table 6.1 with data by site given in Appendices 8.1 and 8.2.

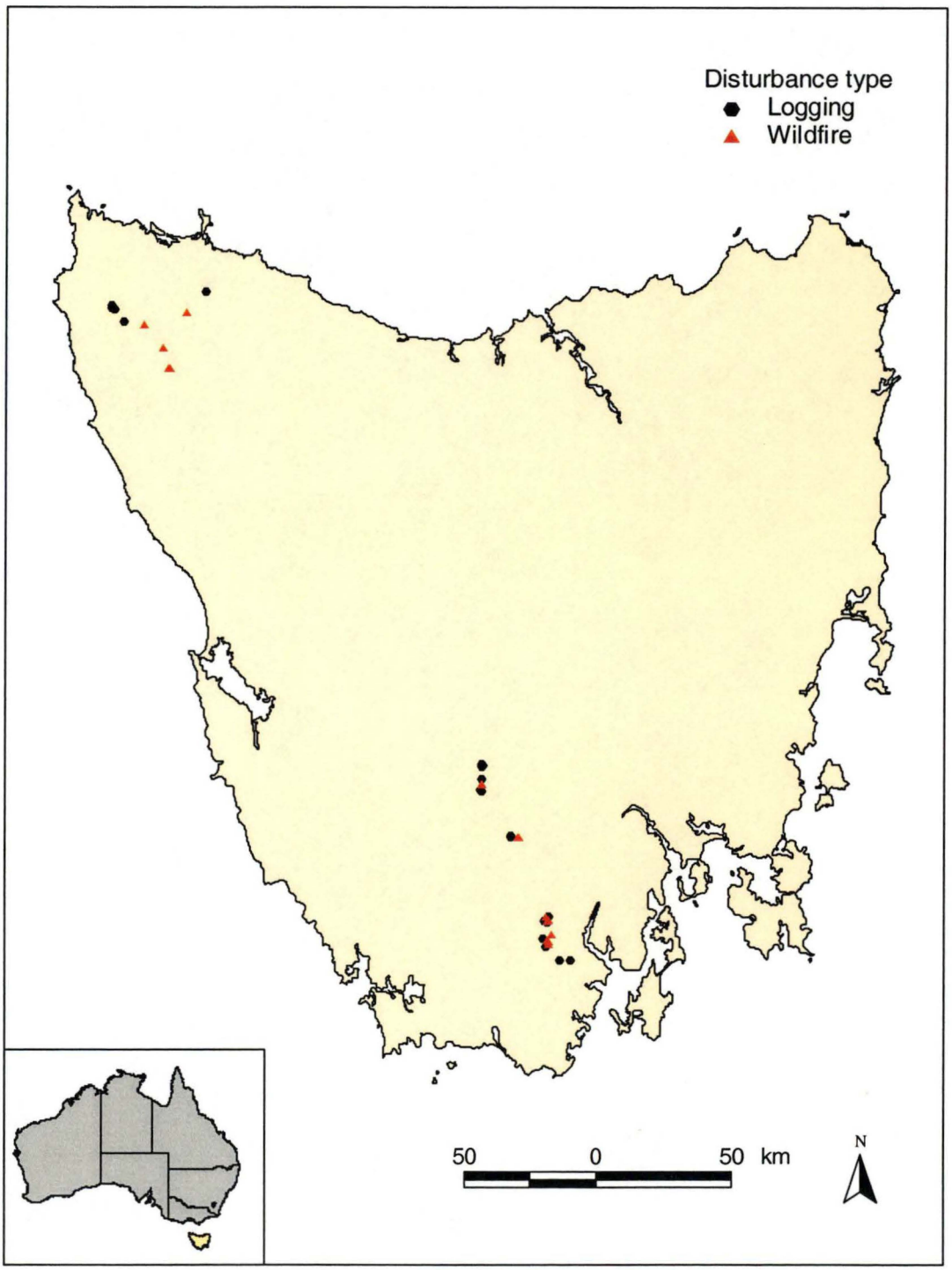


Figure 6.1. Location of logging and wildfire sites in Tasmanian wet eucalypt forest.

Table 6.1. Characteristics for sites disturbed by wildfire or clearfell and burn logging.

Variable	All sites		Logging		Wildfire	
	Mean ± SE	Range	Mean ± SE	Range	Mean ± SE	Range
Altitude (m)	350.24 ± 28.53	60.00 – 660.00	320.96 ± 38.98	60.00 – 573.00	381.96 ± 41.69	95.00 – 660.00
Aspect (°)	203.65 ± 9.69	80.00 – 316.67	202.88 ± 13.87	80.00 – 316.67	204.49 ± 13.80	90.00 – 283.33
Mean annual temperature (°C)	9.76 ± 0.21	7.50 – 12.10	9.95 ± 0.31	8.30 – 12.10	9.56 ± 0.29	7.50 – 11.50
Mean annual rainfall (mm)	1465.00± 25.54	1147.00 – 1888.00	1432.00 ± 31.60	1147.00 – 1615.00	1502.42 ± 40.09	1184 - 1888
Rainfall driest month (mm)	70.30 ± 1.52	55.00 – 83.00	68.15 ± 2.22	55.00 – 81.00	72.63 ± 1.99	59.00 – 83.00
Slope (°)	10.91 ± 0.94	1 – 26	7.12 ± 0.83	1.00 – 14.67	15.01± 1.31	5.00 – 26.00
Latitude (° east)	42.373795 ± 0.12	40.991804 – 43.248477	42.326912 ± 0.18	40.991804 – 43.248477	42.424584 ± 0.18	41.057340 – 43.191667
pH	5.22 ± 0.10	3.50 – 6.50	5.28 ± 0.11	4.00 – 6.00	5.17 ± 0.17	3.50 – 6.50
Total nitrogen (%dry soil weight)	0.35 ± 0.02	0.11 – 0.99	0.37 ± 0.04	0.16 – 0.99	0.32 ± 0.03	0.11 – 0.68
Available phosphorus (ppm)	15.72 ± 3.07	1.51 – 117.33	11.63 ± 1.70	1.96 – 32.64	20.14 ± 6.06	1.51 – 117.33

The 50 sites included 26 sites regenerating from clearfelling between 1961 and 1969 (Table 6.2), and 24 sites burnt by wildfire between 1961 and 1967 (Table 6.3). These periods were chosen because clearfell burning and sowing did not begin as a silvicultural treatment until 1961. In addition, reliable knowledge, maps and reports exist for wildfires and clearfell burn logging during this time. Sites were situated in forests of Northern (8 logged and 7 wildfire sites) Central (10 logged and 8 wildfire sites) and Southern (8 logged and 9 wildfire sites) Tasmania (Figure 6.1). All logged sites were clearfelled and burnt by high intensity burns post harvesting. Wildfire sites were sampled if

a) the fire killed a majority of *Eucalyptus* spp. and rainforest species, i.e. dead trees were evident

b) *Eucalyptus* spp. regeneration was present

c) salvage logging or other logging activities were not evident/recorded

These criteria were adhered so as to replicate as close as possible clearfell burn harvesting methods. Preferably, sites would have spanned a number of different wildfire years and different locations. As discussed by Hickey (1994), practical constraints, such as remote localities and wildfire events limited the selection of sites. An added limitation in the present study was the time needed to sample bryophytes. As a consequence, more than one site was established at some wildfire localities. These practical restrictions limited sampling to few wildfire events with less variation in environmental conditions than would be expected had sites of different localities been available.

Table 6.2. Logging events sampled.
The number in brackets is the number of sites established at each location.

Year	Forest region	Sites location
1961	Southern	Hartz Rd (1)
	Central	Lawrence River Rd (2)
	Central	Nine Rd Junction (2)
	Central	Westfield Rd (3)
1962	Northwest	Lebrunna Rd/Salmon River Rd (5)
1963	Southern	Hermans Rd (1)
	Southern	Johns Link (1)
	Central	Waterfall Creek Rd (2)
1964	Northwest	Salmon River Rd (1)
1966	Southern	Arve Rd (1)
	Southern	Edwards Rd (1)
	Southern	Hartz Rd (1)
	Central	Waterfall Creek Rd (1)
	Northwest	Gahnia Rd (1)
1967	Southern	Edwards Rd/Edwards Rd Spur 1 (2)
1969	Northwest	Black Jay/Leensons Rd (1)

Table 6.3. Wildfire events sampled.
The number in brackets is the number of sites established at each location.

Year	Forest region	Sites location
1961	Northern	South of Lost Hill (2)
	Northern	Rapid River Rd (2)
1962	Northern	Tayatea Bridge (1)
1966	Southern	Blue Hill (3)
	Southern	Crib Hill (5)
	Central	Westfield Quarry/Nine Rd (5)
	Central	Ted Ranselys Rd (3)
	Northern	Chester Creek (2)
1967	Southern	Edwards Rd (1)

Vegetation sampling

For details of vegetation sampling refer to Chapter 2. Nomenclature follows Dalton *et al.* (1991) for mosses, Ratkowsky (1987) for liverworts and Buchanan (1999) for vascular plants, except where authorities are given.

Environmental variables

Environmental measurements were recorded from each of the three transects. A single value for each site was used for latitude (° east), geology, mean annual temperature (°C), mean annual rainfall (mm), rainfall of the driest month (mm), total nitrogen (%dry soil weight), available phosphorus (ppm) and the number of substrates per site. A mean value was used for remaining variables; aspect (°), slope (°), pH, altitude (m), % canopy cover, % cover of above ground substrates and basal area of: rainforest trees (as defined by Jarman *et al.* 1991) (see Appendix 8.3); *Eucalyptus* spp.; *Dicksonia antarctica,* and dead trees (m^2 ha^{-1}, Bitterlich wedge method, Mueller-Dombois and Ellenberg 1974). A binary variable was used for disturbance type (1 = logging, 2 = wildfire). Details of variable ranges are given in Table 6.1. For further details of variables see Chapter 2.

Analysis

Individual species association with logging or wildfire

The significance of the associations between individual bryophyte and vascular species and logging or wildfire was determined using chi square in all cases where expected values were ≥ 5. This indicates which species are more likely to be found in a particular forest disturbance type.

Site environmental characteristics

By combining site environmental characteristics (altitude, aspect, slope, rainfall of the driest month, mean annual rainfall, mean annual temperature, latitude, total nitrogen, available phosphorus, pH), Analysis of similarities (ANOSIM) (Minchin 1990; Clarke 1993) could be used to assess differences in environment between groups of wildfire and logging sites. ANOSIM considers the differences in floristics between groups of samples and compares those differences found within groups. ANOSIM constructs a test statistic (R). This statistic is a valuable measure of the degree of separation of sites. The denominator is such that *R* can never lie outside the range –1 to 1. If R = 1 then all quadrats within groups are more similar to each other than any quadrats from different

groups and if R = 0, then the null hypothesis is true, the dissimilarities between and within groups will be the same on average. It is possible for R to be significantly different from zero yet inconsequentially small, if there are many quadrats at each site (Clarke 1993). Values smaller than zero indicate greater dissimilarity among samples within groups, than occurs between groups. The significance of R was calculated by comparing the test statistic to 1000 random permutations. The significance levels of pairwise tests are not adjusted by ANOSIM to consider multiple comparisons. Values of 'p' falling close to 0.05 should be interpreted with care (Clarke 1993). The environmental variables were standardised to equal totals; by dividing sample variable values for each sample by the total of that sample, each sample has a total of 1.0. The Gower metric was applied to all variables.

Differences in % cover of above ground substrates and basal area of tree species between logging and wildfire groups for all sites (n = 50) and for logging and wildfire sites within each latitudinal band of forest, were evaluated using a two-sample t test. The percentage cover of ground = 100 - % cover of above ground substrates. Therefore it was not analysed here.

Species composition

The indirect ordination method, non-metric multi-dimensional scaling (NMDS) was used to produce separate ordinations of bryophyte and vascular species composition for all (number of sites (n) = 50 sites) and for sites within each latitudinal band (Central, n = 18; Northern, n = 15; Southern, n = 17) (DECODA, Minchin 1990). Henceforth, all sites data will be referred to as n = 50. All ordinations used the recommended Bray-Curtis dissimilarity co-efficient (Faith *et al.* 1987). NMDS was used in this study because compared to other ordination methods, it was found to be a more robust ordination method for community data (Kenkel and Orlóci 1986; Minchin 1987). The NMDS ordinations were performed in 1 to 4 dimensions using 10 different random initial configurations. A plot of stress versus the number of dimensions was used to select the dimension that adequately reflected the differences in species compositions among samples. For n = 50, two-dimensional ordinations were selected for vascular plants and bryophyte species compositions. For Northern, Central and Southern forest, two-dimensional ordinations adequately represented both vascular plant and bryophyte species data. The significance of species composition between groups of wildfire and

logging sites for n = 50 and for Northern, Central and Southern forests was tested using an Analysis of Similarities (ANOSIM, Clarke 1993), using DECODA (Minchin 1990, 1000 permutations). All ordinations were rotated (Procrustean analysis, DECODA, Minchin 1990) so the positions of sites best fitted those in the two-dimensional bryophyte ordination.

For Northern, Central and Southern forest, relationships between bryophyte and vascular species composition and environmental variables were explored initially using vector fitting (Kantvilas and Minchin 1989). The technique maximises the linear correlation of a given variable within the ordination. The length of the line from the zero origin to the co-ordinates for the variable depicts the strength of the relationship with species composition. The significance of each relationship was tested using permutation (1000 permutations).

Where differences between logging and wildfire site groups for Northern, Central and Southern forest were detected by ANOSIM for both bryophyte species composition and environmental variables, further analyses to detect if floristic differences were due to logging/wildfire and/or other environmental characteristics were undertaken using Generalised Linear Modelling (GLM). Generalised linear modelling is a form of regression that performs univariate analysis of variance and analysis of covariance for a response variable (McCullagh and Nelder 1989). The general predictor (independent) variables are quantitative or represent a mixture of quantitative and qualitative data. The primary response variables used were the logging/wildfire vector scores for central and northern forest sites. Each response variable was analysed separately, with the effect of disturbance tested by adding the environmental variables as continuous covariates to the model after adjusting for the binary logging/wildfire predictor variable. Predictor variables included mean annual temperature, mean annual rainfall, rainfall of the driest month, total nitrogen, available phosphorus, pH, slope and aspect. The last was included as a categorical covariate. Eliminating non-significant variables and refitting the model obtained minimal significant models. Model fitting and testing was carried out using MINITAB (Minitab release 13.1 2000), using the GLM procedure under ANOVA. The F statistic and its p-value are calculated from the adjusted sums of squares.

Where a significant difference in bryophyte species composition was found to exist between logging and wildfire groups within Northern, Central and Southern forest (by ANOSIM and GLM), trends in species composition were summarised by ordering samples along the vector for logging/wildfire and producing ordered tables. Species occurring in less than 5 sites were excluded and the order of remaining species defined by their weighted average along the vector using DECODA (Minchin 1990).

Results

A total of 204 bryophyte taxa and 98 vascular plant taxa were recorded from the 50 sites. For bryophytes, this included 95 moss and 109 liverwort species. Appendix 8.9 lists percentage frequency of each species. Of the bryophyte species, three occurred at all sites: *Bazzania involuta*, *Lepidozia ulothrix* and *Ptychomnion aciculare*. The remaining commonly recorded species were *Rhaphidorrhynchium amoenum* (occurring at 98% of sites), *Heteroscyphus coalitus* (94%), *Leptotheca gaudichaudii* (94%), *Rhizogonium novae-hollandiae* (94%), *Teleranea patentissima* (92%), and *Wijkia extenuata* (92%). Twelve mosses (12.63%) and 21 liverworts (19.27%) were recorded only once. For vascular plants, the most commonly recorded were *Dicksonia antarctica* (occurring on 80% of sites), *Polystichum proliferum* (76%), *Histiopteris incisa* (66%), *Pteridium esculentum* (66%), *Nothofagus cunninghamii* (64%), *Grammitis* spp. (56%), *Gahnia grandis* (52%) and *Pomaderris apetala* (50%). Thirty-two vascular species (32.65%) were recorded only once. No introduced species were recorded.

Individual species association with logging or wildfire

One vascular plant species, *Coprosma quadrifida*, and four moss species (*Fissidens pallidus*, *Plagiothecium lamprostachys* (Hampe) Jaeg., *Rhizogonium distichum* and *Achrophyllum dentatum)* occurred more commonly in logging than wildfire regeneration (Table 6.4). One moss species (*Dicranoloma robustum*), six liverwort species (*Riccardia* spp., *Zoopsis leitgebiana*, *Kurzia compacta*, *Kurzia hippurioides*, *Lepidozia procera* and *Gackstroemia weindorferi*) and three vascular plant species (*Monotoca glauca*, *Hymenophyllum peltatum* and *Nematolepis squamea* ssp. *squamea*) were more frequently found in wildfire than logging regeneration. One of the three vascular species (*Hymenophyllum peltatum*) is an epiphytic fern. Of the liverwort species, only *Riccardia* spp. is a thallose liverwort.

*Table 6.4. Vascular and bryophyte species with a significant difference in frequency between logging and wildfire regeneration. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, ns = not significant.*

Species	Occurrence in sites		Probability
	Logging	Wildfire	
	Logging > wildfire		
Vascular species			
Coprosma quadrifida	11	3	0.019*
Bryophyte species			
Fissidens pallidus	16	6	0.009**
Plagiothecium lamprostachys (Hampe) Jaeg.	17	7	0.010*
Rhizogonium distichum	19	9	0.011*
Achrophyllum dentatum	22	14	0.039*
	Wildfire > logging		
Vascular species			
Monotoca glauca	6	14	0.011 *
Hymenophyllum peltatum	8	14	0.049*
Nematolepis squamea ssp. *squamea*	9	15	0.049*
Bryophyte species			
Riccardia spp.	3	12	0.003**
Zoopsis leitgebiana	7	13	0.049*
Kurzia compacta (Steph.) Grolle	8	15	0.025*
Kurzia hippurioides	8	19	0.001***
Dicranoloma robustum	11	18	0.019*
Lepidozia procera	13	19	0.032*
Gackstroemia weindorferi	13	22	0.001***

Site environmental characteristics

ANOSIM established that there was no difference in environmental characteristics between logging and wildfire sites (n = 50) (R = 0.0438 p = 0.089). When sites within latitudinal bands were considered, ANOSIM revealed environmental differences between logging and wildfire sites in both the Northern and Central forest (Northern R = 0.7354, p = 0.000; Central R = 0.3342, p = 0.005), but not the Southern forest (R = 0.0217, p = 0.2745).

There were few differences in % cover of above ground substrates and basal area of vascular plant species between logging and wildfire for all sites (n = 50) (Table 6.5). Significant differences in % cover of substrates were found for rock, dead tree and total above ground substrate cover, with all cover values greater in groups of wildfire sites than logging sites (rock: logging mean 0.64 ± 0.20, wildfire mean 3.38 ± 1.10, p = 0.02; dead trees: logging 0.37 ± 0.17, wildfire 1.49 ± 0.39, p = 0.014; total above ground substrate cover: logging 20.29 ± 0.97, wildfire 25.50 ± 2.20 p = 0.035). Similarly, the basal area of dead trees and *Nematolepis squamea* ssp. *squamea* had greater values in groups of wildfire sites than logging sites (dead trees: logging 0.46 ± 0.15, wildfire 3.42 ± 1.06, p = 0.011; *Nematolepis squamea* ssp. *squamea*: logging 0.52 ± 0.22, wildfire 2.24 ± 0.80 p = 0.047). Basal area of *Nothofagus cunninghamii*, *Pomaderris apetala*, and total basal area were greater in groups of logging sites than wildfire sites (*Nothofagus cunninghamii*: logging 6.25 ± 2.10, wildfire 1.34 ± 0.60, p = 0.032; *Pomaderris apetala*: logging 19.00 ± 4.78, wildfire 7.67 ± 2.78 p = 0.047; total basal area: logging 65.77 ± 4.35, wildfire 56.75 ± 3.57 p = 0.038). Dis

There were also very few significant differences in % cover of above ground substrates and basal area of vascular plant species between logging and wildfire for Northern, Central and Southern forest (Tables 6.6 to 6.8 respectively). No significant differences were found for % cover of above ground substrates and basal area of vascular plant species between groups of logging and wildfire sites for the Southern forest. No significant differences were found for % cover of above ground substrates between groups of logging and wildfire sites for Northern forest. However, in terms of basal area, significant differences were found between regeneration types for basal area of *Dicksonia antarctica* (logging 6.92 ± 12.09, wildfire 0.58 ± 0.47, p = 0.021) and total basal area (logging 64.25 ± 6.47, wildfire 36.77 ± 3.17, p = 0.003). Both have greater

values in logging than wildfire regeneration. For Central forests, significant differences in % cover of substrates were found only for rocks, dead trees and total above ground substrate cover, with greater values found in wildfire than logging regeneration for all substrate types (rock: logging 0.39 ± 0.19, wildfire mean 6.21 ± 2.20, p = 0.033; dead trees: logging 0.02 ± 0.02, wildfire 1.92 ± 0.71, p = 0.032; total above ground substrate cover: logging 19.19 ± 1.60, wildfire 29.67 ± 2.80 p = 0.008). Both the basal area of *Acacia dealbata* and total basal area were significantly different between regeneration groups, with values higher in logging regeneration (*Acacia dealbata*: logging 5.14 ± 1.68, wildfire mean 1.08 ± 0.44, p = 0.041; total basal area: logging 75.00 ± 7.11, wildfire 51.50 ± 4.72, p = 0.016). Both the basal area of *Pomaderris apetala* and all rainforest species were greater in logging regeneration than wildfire regeneration. However, the differences were not significant (Table 6.8).

Species composition and floristic difference (n = 50)

Ordinations of bryophyte species and vascular plant composition data (n = 50) are shown in Figure 6.2. For the bryophyte ordination the two-dimensional solution had a minimum stress value of 0.184 (Figure 6.2a). There is little difference in bryophyte species composition between sites regenerating after wildfire or logging as shown by ANOSIM (R = 0.059, p = 0.045).

Ordination of vascular species composition (n = 50) achieved a minimum stress of 0.249 in two-dimensions and a minimum stress of 0.166 in three dimensions. Although the two dimensional result has a higher stress value, it is shown here (Figure 6.2b) for better portrayal and comparison with the bryophyte species ordination (n = 50). Similar to the results for bryophyte species composition, the data suggest there is little difference between vascular species composition of sites regenerating after wildfire or logging (ANOSIM: R = 0.055, p = 0.043).

*Table 6.5. Percentage cover of above ground substrates and basal area (m^2 ha^{-1}) of vascular species (mean ± SE) for sites grouped by logging (n = 26) and wildfire regeneration (n = 24). $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, ns = not significant. ‡ = Rainforest species are as defined by Jarman* et al. *(1991), (see Appendix 8.3).*

Variable	Logging	Wildfire	p	DF
Percentage cover of above ground substrates				
Log cover	11.11 ± 0.92	12.55 ± 1.2	0.345 ns	44
Fallen branch cover	1.26 ± 0.15	1.20 ± 0.16	0.762 ns	47
Tree cover	3.83 ± 0.38	3.97 ± 0.58	0.845 ns	40
Live roots cover	0.11 ± 0.05	0.25 ± 0.17	0.429 ns	26
Stump cover	1.69 ± 0.41	0.91 ± 0.23	0.101 ns	39
Rock cover	0.64 ± 0.20	3.38 ± 1.10	0.020 *	24
Dead tree cover	0.37 ± 0.17	1.49 ± 0.39	0.014 *	31
Upturned tree base cover	0.82 ± 0.27	0.97 ± 0.39	0.758 ns	41
Dicksonia antarctica cover (vertical, alive)	0.26 ± 0.09	0.30 ± 0.13	0.845 ns	41
Dicksonia antarctica cover (horizontal, dead)	0.19 ± 0.07	0.48 ± 0.28	0.315 ns	25
Total above ground substrate cover	20.29 ± 0.97	25.5 ± 2.20	0.035 *	32
Basal area of vascular species				
Dead trees	0.46 ± 0.15	3.42 ± 1.06	0.011 *	23
Stumps	0.03 ± 0.03	0.06 ± 0.04	0.521 ns	40
Acacia dealbata	2.31 ± 0.80	0.70 ± 0.21	0.060 ns	28
Acacia melanoxylon	0.54 ± 0.22	0.42 ± 0.20	0.682 ns	47
Acacia riceana	0.08 ± 0.06	0.17 ± 0.17	0.614 ns	28
Acacia verticillata	0.00	0.06 ± 0.06	0.328 ns	23
Anopterus glandulosus ‡	0.00	0.06 ± 0.06	0.328 ns	23
Atherosperma moschatum ‡	2.31 ± 1.58	1.89 ± 1.35	0.841 ns	47
Banksia marginata	0.00	0.04 ± 0.04	0.328 ns	23
Cyathodes glauca	0.04 ± 0.04	0.00	0.327 ns	23
Dicksonia antarctica ‡	6.41 ± 1.25	4.81 ± 1.62	0.437 ns	44
Eucalyptus brookeriana	0.95 ± 0.42	0.33 ± 0.33	0.257 ns	46
Eucalyptus delegatensis	5.92 ± 2.70	5.33 ± 2.35	0.870 ns	47
Eucalyptus obliqua	7.70 ± 2.19	12.42 ± 3.22	0.232 ns	41
Eucalyptus regnans	9.98 ± 2.40	8.17 ± 2.50	0.604 ns	47
Eucryphia lucida ‡	0.05 ± 0.04	1.56 ± 0.94	0.122 ns	23
Leptospermum scoparium	0.40 ± 0.40	0.00	0.327 ns	23
Leptospermum spp.	0.00	0.60 ± 0.60	0.328 ns	23
Monotoca glauca ‡	0.02 ± 0.02	0.30 ± 0.20	0.196 ns	23
Nematolepis squamea ssp. *squamea*	0.52 ± 0.22	2.24 ± 0.80	0.047 *	26
Nothofagus cunninghamii ‡	6.25 ± 2.10	1.34 ± 0.60	0.032 *	29
Olearia argophylla ‡	2.34 ± 1.20	1.53 ± 1.16	0.632 ns	47
Phyllocladus asplenifolius ‡	0.20 ± 0.14	0.20 ± 0.14	0.955 ns	47
Pittosporum bicolor ‡	0.21 ± 0.14	0.33 ± 0.24	0.656 ns	38
Pomaderris apetala	19.00 ± 4.78	7.67 ± 2.78	0.047 *	39
Prostanthera lasianthos	0.03 ± 0.03	0.11 ± 0.11	0.459 ns	25
Tasmannia lanceolata ‡	0.05 ± 0.05	0.00	0.327 ns	23
Total basal area	65.77 ± 4.35	53.75 ± 3.57	0.038 *	46
Basal area of rainforest species	11.44 ± 3.03	7.20 ± 2.49	0.285 ns	46
Basal area of *Eucalyptus* spp.	24.54 ± 2.20	26.25 ± 2.55	0.613 ns	46

*Table 6.6. Percentage cover of above ground substrates and basal area (m^2 ha^{-1}) of vascular species (mean ± SE) for Southern forest sites grouped by logging (n = 8) and wildfire regeneration (n = 9). $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, ns = not significant. ‡ = Rainforest species are as defined by* Jarman et al. *(1991), (see Appendix 8 3).*

Variable	Logging	Wildfire	p	DF
Percentage cover of above ground substrates				
Log cover	15.88 ± 1.50	15.39 ± 2.20	0.856 ns	13
Fallen branch cover	0.70 ± 0.22	1.23 ± 0.36	0.228 ns	13
Tree cover	2.51 ± 0.46	3.86 ± 0.69	0.126 ns	13
Live roots cover	0.03 ± 0.02	0.43 ± 0.40	0.356 ns	8
Stump cover	1.12 ± 0.68	0.65 ± 0.24	0.534 ns	8
Rock cover	1.59 ± 0.45	3.47 ± 1.80	0.335 ns	9
Dead tree cover	0.62 ± 0.41	1.91 ± 0.77	0.163 ns	12
Upturned tree base cover	0.64 ± 0.35	1.13 ± 0.65	0.519 ns	12
Dicksonia antarctica cover (vertical, alive)	0.18 ± 0.15	0.40 ± 0.28	0.489 ns	12
Dicksonia antarctica cover (horizontal, dead)	0.25 ± 0.16	1.10 ± 0.71	0.274 ns	8
Total above ground substrate cover	23.51 ± 1.40	29.60 ± 3.90	0.170 ns	10
Basal area of vascular species				
Stumps	0.08 ± 0.08	0.14 ± 0.10	0.622 ns	14
Dead trees	0.42 ± 0.12	2.96 ± 1.34	0.095 ns	8
Acacia dealbata	1.08 ± 0.66	0.88 ± 0.36	0.800 ns	10
Acacia melanoxylon	0.16 ±0.16	0.00	0.351 ns	7
Acacia riceana	0.25 ± 0.18	0.44 ± 0.44	0.692 ns	10
Atherosperma moschatum ‡	0.00	4.52 ± 3.51	0.234 ns	8
Banksia marginata	0.00	0.08 ± 0.08	0.347 ns	8
Cyathodes glauca	0.08 ± 0.08	0.00	0.351 ns	7
Dicksonia antarctica ‡	5.58 ± 2.00	7.18 ± 3.40	0.690 ns	12
Eucalyptus delegatensis	11.34 ± 6.78	4.67 ± 3.26	0.396 ns	10
Eucalyptus obliqua	4.50 ± 1.74	19.04 ± 6.88	0.071 ns	9
Eucalyptus regnans	8.25 ± 3.53	4.38 ± 2.48	0.386 ns	12
Eucryphia lucida ‡	0.00	0.88 ± 0.88	0.347 ns	9
Leptospermum scoparium	1.24 ± 1.24	0.00	0.351 ns	7
Nematolepis squamea ssp. *squamea*	0.50 ± 0.28	0.82 ± 0.58	0.637 ns	11
Nothofagus cunninghamii ‡	0.42 ± 0.24	0.14 ± 0.14	0.380 ns	11
Olearia argophylla ‡	0.50 ± 0.42	3.18 ± 3.20	0.416 ns	8
Phyllocladus asplenifolius ‡	0.40 ± 0.40	0.00	0.351 ns	7
Pittosporum bicolor ‡	0.00	0.28 ± 0.28	0.347 ns	9
Pomaderris apetala	20.83 ± 7.54	19.26 ± 5.58	0.870 ns	13
Total basal area	55.75 ± 8.18	68.96 ± 4.15	0.181 ns	10
Basal area of rainforest species	1.33 ± 0.56	9.04 ± 5.67	0.214 ns	8
Basal area of *Eucalyptus* spp.	24.08 ± 4.60	28.08 ± 5.60	0.592 ns	14

*Table 6.7. Percentage cover of above ground substrates and basal area (m^2 ha^{-1}) of vascular species (mean ± SE) for Northern forest sites grouped by logging (n = 8) and wildfire regeneration (n = 7). $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, ns = not significant. ‡ = Rainforest species are as defined by Jarman* et al. *(1991), (see Appendix 8.3)*

Variable	Logging	Wildfire	p	DF
Percentage cover of above ground substrates				
Log cover	8.07 ± 0.50	10.04 ± 0.97	0.107 ns	9
Fallen branch cover	1.52 ± 0.31	1.21 ± 0.26	0.458 ns	12
Tree cover	4.65 ± 0.95	2.35 ± 0.65	0.068 ns	12
Live roots cover	0.10 ± 0.05	0.31 ± 0.27	0.488 ns	6
Stump cover	1.73 ± 0.60	0.93 ± 0.27	0.252 ns	9
Rock cover	0.00	0.03 ± 0.03	0.356 ns	6
Dead tree cover	0.55 ± 0.38	0.45 ± 0.27	0.829 ns	12
Upturned tree base cover	1.97 ± 0.71	0.06 ± 0.06	0.059 ns	7
Dicksonia antarctica cover (vertical, alive)	0.07 ± 0.05	0.06 ± 0.06	0.907 ns	12
Dicksonia antarctica cover (horizontal, dead)	0.07 ± 0.07	0.00	0.351 ns	7
Total above ground substrate cover	18.43 ± 1.60	15.43 ± 1.20	0.153 ns	12
Basal area of vascular species				
Dead trees	0.75 ± 0.34	1.34 ± 1.34	0.687 ns	6
Acacia melanoxylon	1.08 ± 0.64	1.04 ± 0.64	0.975 ns	12
Acacia verticillata	0.00	0.20 ± 0.20	0.356 ns	7
Atherosperma moschatum ‡	0.17 ± 0.17	0.67 ± 0.56	0.425 ns	7
Dicksonia antarctica v	6.92 ± 2.09	0.58 ± 0.47	0.021 *	7
Eucalyptus brookeriana	3.08 ± 1.06	1.14 ± 1.14	0.236 ns	12
Eucalyptus obliqua	20.50 ± 4.14	18.10 ± 3.30	0.659 ns	12
Eucryphia lucida ‡	0.16 ± 0.10	4.10 ± 3.00	0.229 ns	6
Leptospermum spp.	0.00	2.08 ± 2.08	0.356 ns	6
Monotoca glauca ‡	0.00	0.28 ± 0.28	0.356 ns	6
Nematolepis squamea ssp. *squamea*	1.08 ± 0.60	2.00 ± 0.94	0.433 ns	10
Nothofagus cunninghamii ‡	13.17 ± 5.27	2.86 ± 1.86	0.102 ns	8
Olearia argophylla ‡	0.60 ± 0.40	0.00	0.195 ns	7
Phyllocladus asplenifolius ‡	0.16 ± 0.16	0.10 ± 0.10	0.711 ns	11
Pittosporum bicolor ‡	0.66 ± 0.46	0.76 ± 0.76	0.917 ns	9
Pomaderris apetala	15.67 ± 8.58	1.52 ± 1.14	0.146 ns	7
Tasmannia lanceolata ‡	0.16 ± 0.16	0.00	0.351 ns	7
Total basal area	64.25 ± 6.47	36.77 ± 3.17	0.003 **	10
Basal area of rainforest species	15.08 ± 5.08	8.76 ± 4.66	0.377 ns	12
Basal area of *Eucalyptus* spp.	20.50 ± 4.14	18.10 ± 3.30	0.659 ns	12

*Table 6.8. Percentage cover of above ground substrates and basal area (m^2 ha^{-1}) of vascular species (mean ± SE) for Central forest sites grouped by logging (n = 10) and wildfire regeneration (n = 8). $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, ns = not significant. ‡ = Rainforest species are as defined by* Jarman et al. *(1991), (see Appendix 8 3).*

Variable	Logging	Wildfire	p	DF
Percentage cover of above ground substrates				
Log cover	9.73 ± 1.20	11.57 ± 2.20	0.485 ns	11
Fallen branch cover	1.51 ± 0.15	1.15 ± 0.20	0.168 ns	13
Tree cover	4.23 ± 0.38	5.50 ± 1.30	0.386 ns	8
Live roots cover	0.36 ± 0.22	0.00	0.138 ns	9
Stump cover	2.12 ± 0.81	1.17 ± 0.61	0.360 ns	15
Rock cover	0.39 ± 0.19	6.21 ± 2.20	0.033 *	7
Dead tree cover	0.02 ± 0.02	1.92 ± 0.71	0.032 *	7
Upturned tree base cover	0.29 ± 0.16	1.58 ± 0.89	0.195 ns	7
Dicksonia antarctica cover (vertical, alive)	0.49 ± 0.18	0.38 ± 0.23	0.711 ns	14
Dicksonia antarctica cover (horizontal, dead)	0.23 ± 0.11	0.19 ± 0.10	0.814 ns	15
Total above ground substrate cover	19.19 ± 1.60	29.67 ± 2.80	0.008 **	11
Basal area of vascular species				
Dead trees	0.27 ± 0.27	5.75 ± 2.46	0.062 ns	7
Acacia dealbata	5.14 ± 1.68	1.08 ± 0.44	0.041 *	10
Acacia melanoxylon	0.40 ± 0.18	0.34 ± 0.18	0.799 ns	15
Anopterus glandulosus ‡	0.00	0.33 ±0.33	0.351 ns	7
Atherosperma moschatum ‡	5.87 ± 3.96	0.00	0.173 ns	9
Dicksonia antarctica ‡	6.67 ± 2.40	5.84 ± 2.80	0.825 ns	14
Eucalyptus delegatensis	6.34 ± 4.40	10.75 ± 5.72	0.548 ns	13
Eucalyptus regnans	19.34 ± 3.85	19.58 ± 4.97	0.969 ns	14
Eucryphia lucida ‡	0.00	0.08 ±0.08	0.351 ns	7
Monotoca glauca ‡	0.06 ± 0.06	0.66 ± 0.58	0.336 ns	7
Nematolepis squamea ssp. *squamea*	0.06 ± 0.06	4.08 ± 2.20	0.099 ns	7
Nothofagus cunninghamii ‡	5.40 ± 2.67	1.34 ± 0.68	0.170 ns	10
Olearia argophylla ‡	5.20 ± 3.00	1.00 ± 0.50	0.192 ns	9
Phyllocladus asplenifolius ‡	0.04 ± 0.04	0.26 ± 0.20	0.335 ns	7
Pomaderris apetala	20.20 ± 9.08	0.00	0.053 ns	9
Prostanthera lasianthos	0.00	0.32 ± 0.32	0.351 ns	7
Total basal area	75.00 ± 7.11	51.50 ± 4.72	0.016 *	14
Basal area of rainforest species	16.60 ± 6.08	3.75 ± 0.93	0.066 ns	9
Basal area of *Eucalyptus* spp.	25.67 ± 3.60	30.33 ± 3.02	0.336 ns	15

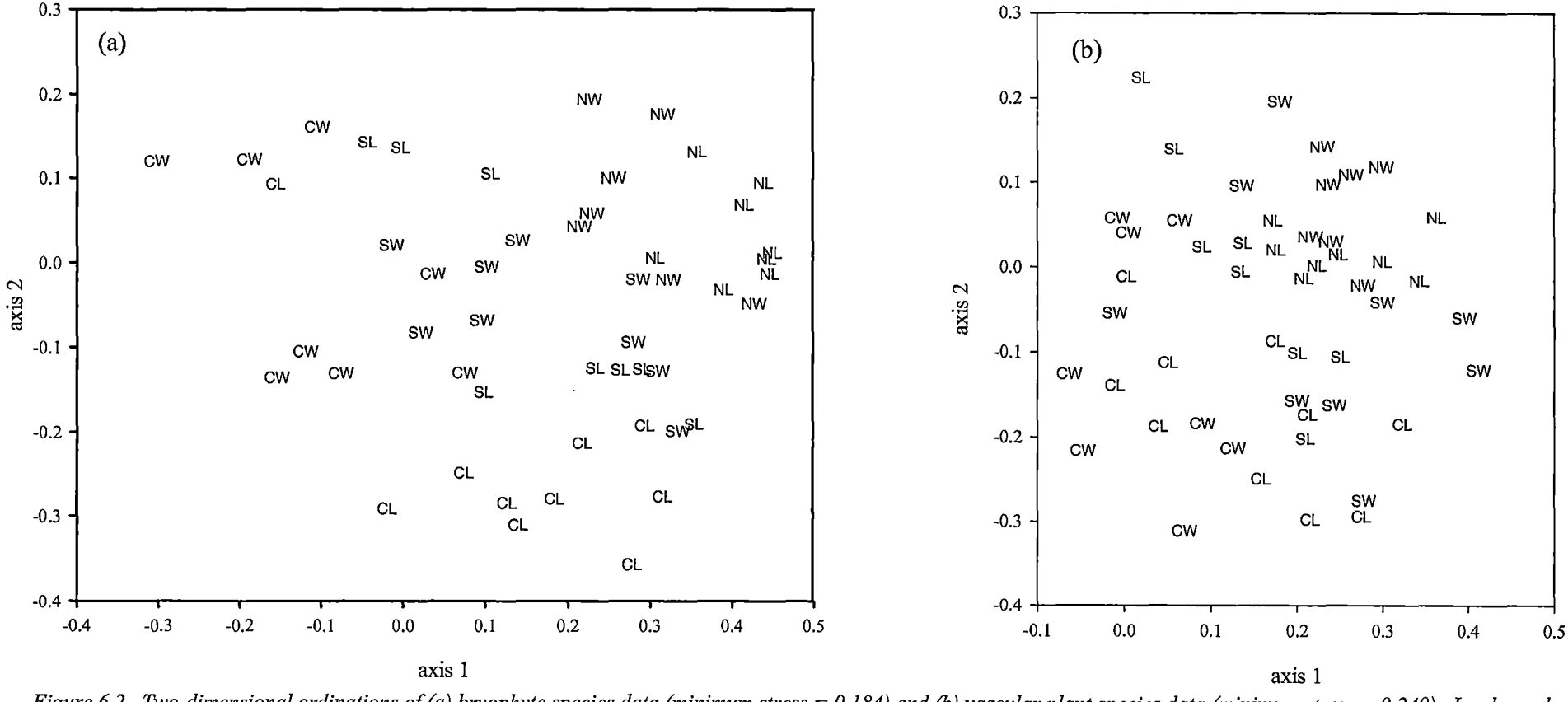


Figure 6.2. Two-dimensional ordinations of (a) bryophyte species data (minimum stress = 0.184) and (b) vascular plant species data (minimum stress = 0.249). L = logged sites, W = wildfire sites, C = Central forest, S = Southern forest, N = Northern forest.

Bryophyte species composition– Northern, Central and Southern forest

The bryophyte species composition ordination (n = 50, Figure 6.2a) suggests there may be a distinction between groups of sites regenerating after wildfire or logging within some forest areas. Ordinations of sites from the Northern, Central and Southern forest are shown in Figure 6.3. The lack of difference in species composition between sites regenerating after wildfire or logging in Southern forests is confirmed by ANOSIM (Figure 6.3a, R = - 0.0727, p = 0.821). There appears to be a difference in groups of sites regenerating from wildfire and logging in the Northern forests (Figure 6.3c, R = 0.3156, p = 0.009). For Central sites, there appears to be a distinct difference in species composition between sites regenerating after wildfire or logging (Figure 6.3e, R = 0.5122, p = 0.001). One site regenerating after logging (84L) is more similar in species composition to wildfire than logging sites.

The results of fitting environmental variables as vectors to the Southern, Northern and Central ordinations are summarised in Table 6.9. The maximum correlation of the variables with sites scores in the ordination and their significance are shown. Environmental variables with significant correlations are shown in Figures 6.3b, 6.3d and 6.3f for bryophyte species data. For Southern forest sites, a number of environmental variables were related to bryophyte species composition (Figure 6.3b). The vector for logging/wildfire was not significantly related to species composition. Fewer environmental variables are related to bryophyte species composition of Northern forest sites (Figure 6.3d). The vector for basal area of *Dicksonia antarctica* is negatively related to bryophyte species compositon after wildfire. For Central forest sites, the basal area of dead trees and altitude are related to bryophyte species composition after wildfire regeneration (Figure 6.3f). In contrast mean annual temperature, % canopy cover and total nitrogen are related to species after logging.

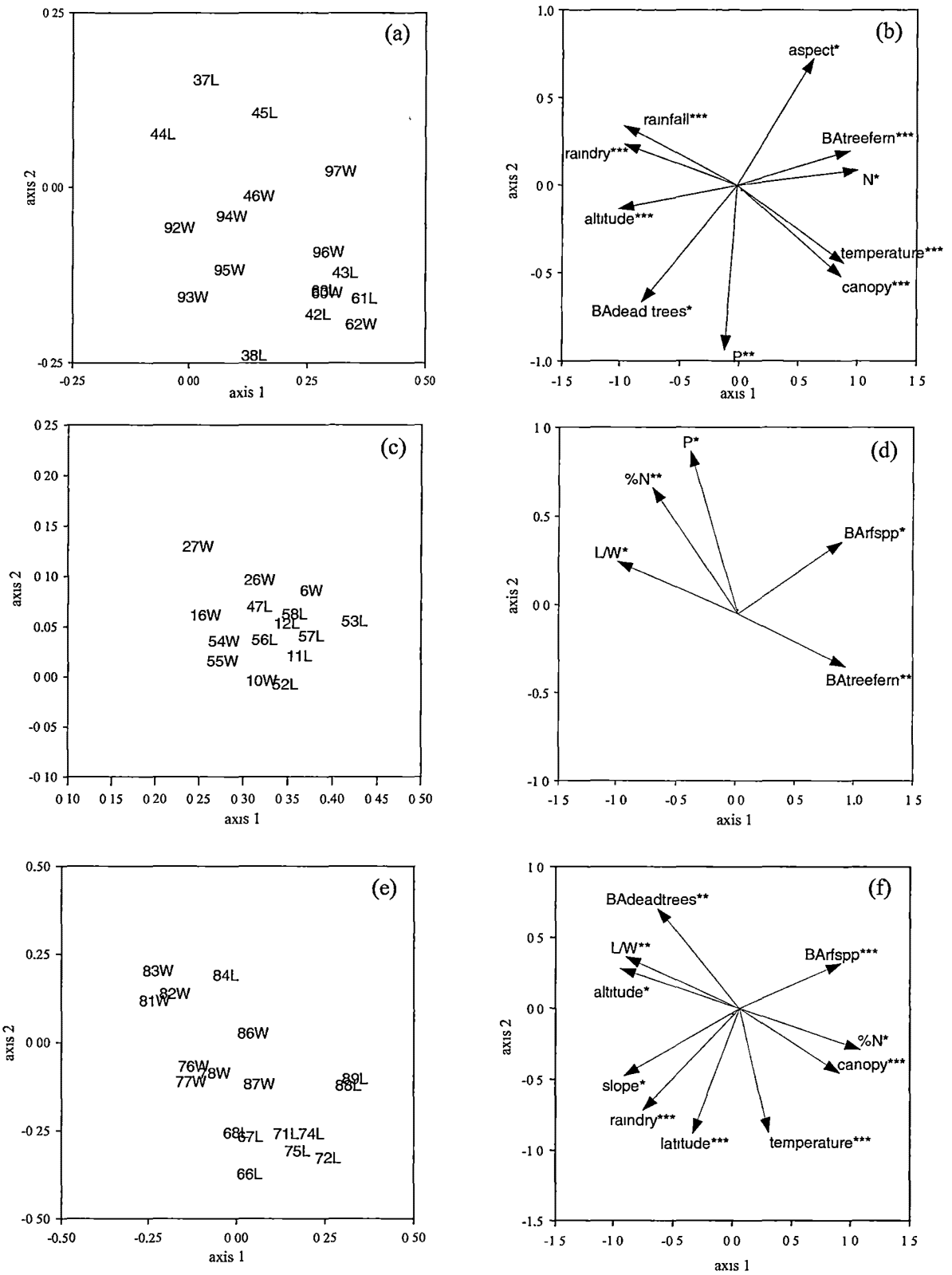


Figure 6.3. Two-dimensional ordination of bryophyte species data (a, c, e), with vectors of significant correlation (b, d, f). (a – b) Southern forest, minimum stress = 0.126; (c – d) Northern forest, minimum stress = 0.176; (e – f) Central forest, minimum stress = 0.113. Abbreviations: L = Logging, W = Wildfire. altitude = Altitude, Aspect = aspect, rainfall = Mean annual rainfall, raindry = Rainfall of the driest month, temperature = Mean annual temperature, slope = Slope, BAdeadtrees = Basal area of dead trees, BArfspp = Basal area of rainforest species, BAtreefern = Basal area of Dicksonia antarctica, *canopy = % Canopy cover, N = Total nitrogen, P = Available phosphorus , L/W = Logging/Wildfire, latitude = Latitude. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$*

Table 6.9. The results of vector fitting site environmental variables into the ordinations of southern, northern and central forest logging and wildfire sites for bryophyte species and vascular plant data. R *value for environmental vectors. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, ns = not significant. Dash indicates variable missing from samples. Rainforest species as defined by Jarman* et al *(1991).*

	Bryophyte species			Vascular plants		
	Southern	Northern	Central	Southern	Northern	Central
Altitude (m)	0.80***	0.51	0.67*	0.66*	0.63*	0.49
Aspect (°)	0.64*	0.40	0.24	0.66*	0.46	0.43
Slope (°)	0.47	0.37	0.61*	0.41	0.24	0.23
Latitude (° east)	0.36	0.50	0.81***	0.61	0.48	0.70*
Mean annual rainfall (mm)	0.86***	0.47	0.25	0.68*	0.60	0.13
Rainfall of the driest month (mm)	0.88***	0.49	0.84***	0.70*	0.60	0.31
Mean annual temperature (°C)	0.85***	0.59	0.78**	0.67*	0.66*	0.74***
Basal area of dead trees	0.64*	0.36	0.72**	0.31	0.59	0.67**
Basal area rainforest species	0.46	0.67*	0.77**	0.49	0.60	0.58*
Basal area *Eucalyptus* spp.	0.45	0.33	0.34	0.58	0.55	0.26
Basal area *Dicksonia antarctica*	0.78***	0.74**	0.34	0.85***	0.51	0.42
% Canopy cover	0.73**	0.35	0.80**	0.67**	0.42	0.89***
Nº of substrate types per site	0.37	0.21	0.30	0.14	0.05	0.20
% Cover of above ground substrates	0.55	0.14	0.43	0.78**	0.44	0.43
pH	0.38	0.52	0.42	0.44	0.49	0.31
Total Nitrogen (% dry soil weight)	0.61*	0.79**	0.63*	0.66*	0.51	0.67**
Available Phosphorus (ppm)	0.70**	0.69*	0.31	0.28	0.31	0.41
Carbonate	-	-	0.37	-	-	0.32
Igneous	0.40	0.18	-	0.40	0.18	-
Siliceous	0.40	0.18	0.37	0.40	0.18	0.32
Logging\wildfire	0.16	0.65*	0.76**	0.45	0.57	0.52

Generalised linear modelling

ANOSIM detected differences between logging and wildfire for Central and Northern forest sites for both bryophyte species composition and environmental variables. For sites in Central forest, generalised linear modelling found variation in scores on the logging/wildfire vector were best explained by mean annual temperature and logging/wildfire (Table 6.10).

For sites in Northern forest, generalised linear modelling found that scores on the vector for logging/wildfire were not best explained by logging/wildfire.

An ordered table shows the distribution of species occurring in five or more samples along the logging/wildfire vector for sites in Central forest (Tables 6.11). Only one species, an epiphytic moss *Neckera pennata*, was found exclusively in logged areas. Of species more frequently found in logged than wildfire sites, mosses were more common than liverworts: the epiphytic mosses *Weymouthia cochlearifolia*, *Cyathophorum bulbosum*, *Calyptopogon mnioides*, *Macromitrium archeri*; other mosses, *Achrophyllum dentatum*, *Fissidens tenellus*, *Fissidens pallidus*, *Rhizogonium distichum* and *Lopidium concinnum*; and epiphytic liverworts *Frullania clavata* and *Lejeunea drummondii*. Liverworts were found more frequently than mosses in wildfire sites. The species only found in wildfire regeneration are the liverworts, *Chiloscyphus leucophyllus* and *Kurzia compacta*. Other liverwort species more common in wildfire than logging regeneration include, *Kurzia hippurioides*, *Lepidozia procera*, *Heteroscyphus limosus*, *Marsupidium surculosum* and *Gackstroemia weindorferi*.

Table 6.10. Generalised linear model for response variable logging/wildfire vector scores for Central sites, using adjusted sums of squares for statistical tests.

Analysis of Variance

Term[1]	**Df**	**Sequential sums of squares**	**Adjusted sums of squares**	**Adjusted mean squares**	**F statistic**	**p value**
Mean annual temperature (mm)	1	0.40402	0.13252	0.13252	9.85	0.007
Logging/wildfire	1	0.18267	0.18267	0.18267	13.58	0.002
Error	15	0.20172	0.20172	0.01345		
Total	17	0.78841				

Coefficients

Term[1]	**Coefficient**	**Standard error Coefficient**	**T statistic**	**p value**
Constant	2.1386	0.6761	3.16	0.006
Mean annual temperature (mm)	-0.25544	0.08137	-3.14	0.007
Logging/wildfire	0.11449	0.03107	3.69	0.002

[1] Variables in the model including the binary covariate logging/wildfire. See methods for details.

Table 6.11. Ordered table for bryophyte species occurring in five or more samples along the vector for logging/wildfire for sites in Central forest. M = moss, Lt = liverwort, L = logging, W = wildfire.

Site number		72	89	88	74	75	71	66	67	87	68	86	78	77	76	84	82	81	83
Species		L	L	L	L	L	L	L	L	W	L	W	W	W	W	L	W	W	W
Fissidens tenellus	M	1	1	1	-	1	1	-	-	1	-	-	-	-	-	-	-	-	-
Weymouthia cochlearifolia	M	1	1	1	1	1	1	-	-	-	-	1	-	-	-	-	-	-	-
Frullania clavata	Lt	1	1	1	1	1	1	-	-	1	1	-	-	-	-	-	-	-	-
Neckera pennata	M	1	-	-	1	1	1	-	-	-	1	-	-	-	-	-	-	-	-
Lejeunea drummondii	Lt	1	1	1	1	1	1	-	-	1	-	1	-	-	-	-	-	-	-
Cyathophorum bulbosum	M	1	1	1	1	-	1	-	1	1	-	-	1	-	-	-	-	-	-
Rhizogonium distichum	M	1	1	1	1	1	1	1	1	1	-	-	-	1	-	-	-	-	-
Achrophyllum dentatum	M	1	1	1	1	1	1	1	1	1	1	1	-	-	-	-	-	-	-
Fissidens pallidus	M	1	1	1	-	-	1	1	1	-	1	1	-	-	-	-	-	-	-
Thuidium furfurosum	M	1	-	1	-	1	1	-	1	-	-	-	-	-	1	-	-	-	-
Calyptopogon mnioides	M	1	-	-	1	1	1	-	1	-	-	-	-	-	1	-	-	-	-
Macromitrium archeri	M	-	-	-	1	1	-	1	1	1	-	-	-	-	-	-	-	-	-
Racopilum cuspidigerum (Schwägr) Åongstr var *convolutaceum* (Mull Hal) Zant & Dijk.	M	1	-	-	1	1	1	1	-	1	-	-	-	1	-	-	-	-	-
Lopidium concinnum	M	1	-	-	1	1	1	-	1	1	1	1	-	-	-	-	-	-	-
Plagiothecium lamprostachys (Hampe) Jaeg	M	1	1	1	1	1	1	1	1	-	1	-	-	1	-	1	-	-	-
Camptochaete arbuscula	M	1	1	1	-	1	1	1	1	1	-	-	1	1	-	-	-	-	-
Chloscyphus muricatus	Lt	1	1	1	-	-	-	1	-	1	-	1	-	-	1	-	-	-	-
Thuidium sparsum	M	1	1	1	1	1	1	-	-	1	1	1	-	-	-	-	-	1	-
Heteroscyphus fissistipus	Lt	1	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-	-	-
Radula compacta	Lt	-	-	1	1	-	-	1	-	1	1	1	-	-	-	-	-	-	-
Metzgeria decipiens	Lt	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-	1	-	-
Hypnum cupressiforme	M	1	1	1	1	1	1	1	1	1	1	1	1	-	1	-	1	-	-
Zygodon intermedius	M	1	-	-	1	1	-	-	1	1	1	-	1	-	1	-	-	-	-
Fissidens pungens	M	1	-	-	-	-	1	-	-	1	1	-	-	1	-	-	-	-	-
Orthodontium lineare	M	1	1	-	1	1	1	1	1	1	1	1	1	1	1	-	-	-	-
Frullania prohoscophora	Lt	1	-	1	1	-	1	1	1	1	1	-	1	1	1	-	-	-	-
Heteroscyphus coalitus	Lt	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-
Chloscyphus echinellus	Lt	1	-	1	-	1	-	1	1	1	1	-	-	-	1	-	1	-	-
Frullania falciloba	Lt	1	1	1	1	1	1	-	1	1	1	-	1	1	1	-	-	-	1
Acrocladium chlamydophyllum	M	1	-	-	1	1	1	1	1	1	1	1	1	1	1	-	-	-	-
Fissidens taylorii	M	-	-	-	-	1	-	1	1	-	-	1	1	-	-	-	-	-	-
Lembophyllum divulsum	M	1	-	-	-	1	1	-	1	-	1	-	1	1	1	-	-	-	-
Rosulabryum billardieri var *billardieri* (Schwaegr) Spence	M	-	-	-	1	1	1	1	1	1	1	1	1	1	1	-	-	-	-
Dicranoloma dicarpum	M	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	-	1
Zoopsis argentea	Lt	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	1	-
Rhaphidorrhynchium amoenum	M	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1
Bazzania involuta	Lt	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lepidozia ulothrix	Lt	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ptychomnion aciculare	M	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rhizogonium novae-hollandiae	M	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Warburgiella leucocytus	M	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Wijkia extenuata	M	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Chloscyphus semiteres	Lt	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Leptotheca gaudichaudii	M	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Orthotrichum tasmanicum var. *tasmanicum*	M	-	-	-	-	-	1	1	1	1	1	-	1	1	1	-	-	-	-
Plagiochila strombifolia	Lt	1	-	1	-	-	1	-	-	1	-	-	1	1	1	-	-	1	-
Dicranoloma menziesii	M	-	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	-
Riccardia crassa	Lt	-	-	-	-	1	-	1	1	1	1	1	-	1	-	-	-	1	-
Lepidozia laevifolia	Lt	-	1	-	1	-	1	1	1	1	1	1	1	1	1	-	1	1	-
Dicranoloma robustum var. *setosum*	M	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ulota lutea	M	-	-	-	-	1	-	-	-	1	1	-	-	-	1	1	-	-	-
Plagiochila retrospectans	Lt	-	-	-	1	1	-	-	-	1	-	1	-	-	1	-	-	-	1
Hypnum chrysogaster	M	-	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1
Telaranea patentissima	Lt	-	1	1	1	1	1	-	-	1	1	1	1	1	1	1	1	1	1
Dicranoloma billardieri	M	-	-	-	1	1	1	1	1	1	1	1	-	-	1	1	1	1	1
Campylopus introflexus	M	-	-	-	-	-	-	-	1	1	1	1	-	-	1	1	-	-	-
Chloscyphus latifolius (L.) Engel & Schust.	Lt	-	-	-	-	1	1	-	-	-	1	-	1	1	1	-	-	1	-
Kurzia hippurioides aff.	Lt	1	-	1	-	-	-	-	-	1	-	1	-	1	-	1	1	1	-
Riccardia cochleata	Lt	-	-	-	-	1	-	1	-	1	-	1	1	1	-	1	-	1	-
Ulota viridis	M	-	-	-	-	-	-	-	1	-	1	1	-	-	1	1	-	-	-
Dicranoloma robustum	M	-	1	1	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1
Leptostomum inclinans	M	-	1	-	-	-	-	-	1	-	1	1	1	1	1	-	-	1	1
Polytrichum juniperinum	M	-	-	-	-	-	-	-	1	1	1	1	1	-	-	1	1	-	1
Gackstroemia weindorferi	Lt	-	-	1	-	-	1	-	-	1	-	1	1	1	1	1	1	1	1
Frullania rostrata	Lt	-	1	1	-	-	-	-	-	-	-	1	-	-	1	1	1	1	1
Marsupidium surculosum	Lt	-	-	-	-	-	-	-	-	1	1	-	1	-	-	1	-	-	1
Heteroscyphus limosus	Lt	-	-	-	-	-	1	-	-	-	1	-	1	1	1	-	1	1	-
Ditrichum difficile	M	-	-	-	-	-	-	-	1	1	-	1	-	1	-	-	-	1	1
Lepidozia procera	Lt	-	-	-	-	-	-	-	1	1	-	1	1	1	1	1	1	1	1
Kurzia hippurioides	Lt	-	-	-	-	-	-	-	-	1	-	1	1	1	1	1	1	1	1
Riccardia spp.	Lt	-	-	-	-	-	-	-	-	1	-	1	1	1	1	1	1	1	1
Kurzia compacta (Steph.) Grolle	Lt	-	-	-	-	-	-	-	-	1	-	1	-	1	1	-	1	1	1
Chloscyphus leucophyllus	Lt	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	1	1	1

Vascular species composition – Northern, Central and Southern forest

For the vascular species ordination (n = 50) there appears to be little distinction between groups of sites regenerating after wildfire or logging within Northern, Central and Southern forest. Ordinations of groups of sites for the different forest groups are shown in Figure 6.4. There is no difference in species composition between groups of sites regenerating from wildfire or logging for both Southern and Northern forests (Southern: $R = 0.0974$, $p = 0.132$; Northern: $R = 0.1115$, $p = 0.113$) (Figures 6.4a and 6.4c). There is a difference in vascular species composition for Central forest sites between forest regenerating after wildfire or logging ($R = 0.3233$, $p = 0.003$) (Figure 6.4e).

Vascular species composition of Southern forest sites had similar related environmental variables to those found for bryophyte species composition (Table 6.5, Figure 6.4b). The vector for logging/wildfire was not significantly related to vascular plant variation. Altitude and mean annual temperature are the only variables significantly related to vascular species composition for Northern forest (Figure 6.4d). For Central forest sites, as for bryophyte species composition, basal area of dead trees is positively related to floristic variation after wildfire, whereas mean annual temperature, % canopy cover and total nitrogen are positively related to species composition after logging (Figure 6.4e).

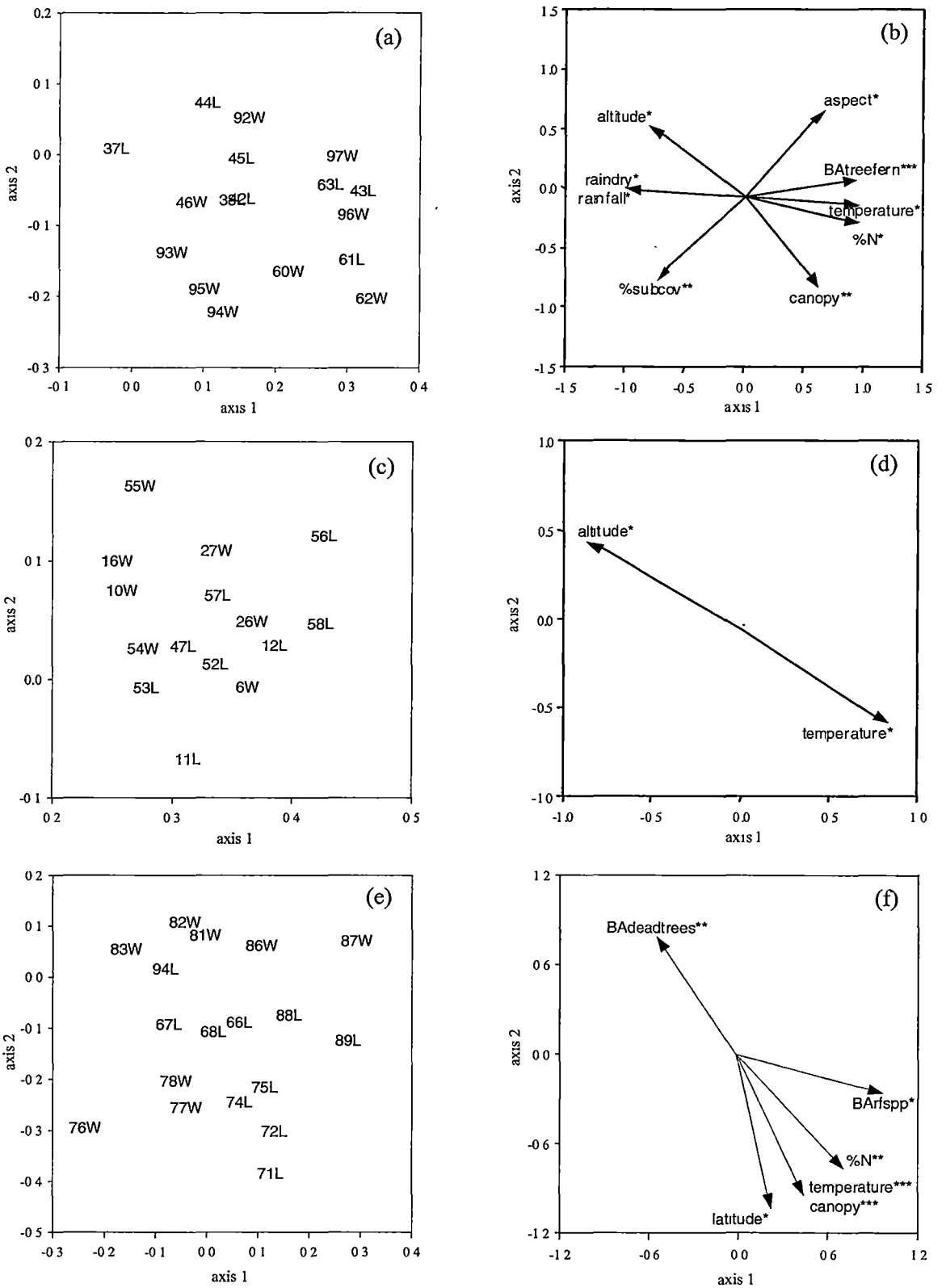


Figure 6.4. Two-dimensional ordination of vascular species data (a, c, e) with vectors of significant correlation (b, d, f). (a - b) Southern forest, minimum stress = 0.139; (c - d) Northern forest, minimum stress = 0.190); (e - f) Central forest, minimum stress = 0.212. Abbreviations: L = Logging, W = Wildfire. altitude = Altitude, aspect = Aspect, rainfall = Mean annual rainfall, raindry = Rainfall of the driest month, temperature = Mean annual temperature, %subcover = % Cover of above ground substrates, BAdeadtrees = Basal area of dead trees, BArfspp = Basal area of rainforest species, BAtreefern = Basal area of Dicksonia antarctica, *canopy = % Canopy cover, N = Total nitrogen, latitude = Latitude. *p < 0.05, **p < 0.01, ***p < 0.001*

Discussion

This study found, for n = 50 sites, the species compositions of bryophyte and vascular plants of mixed forest approximately four decades after regeneration from wildfire differ little from those of clearfell logging regeneration of similar age. Analyses found no environmental or geographic reasons to imply that wildfire areas sampled are different from clearfell areas. When sites were separated into Northern, Central and Southern forest, bryophyte species composition differed between logging and wildfire only in the Central forest. While there was little difference between wildfire and logging regeneration floristics (n = 50), there were differences for other forest attributes. Similarly, wildfire and logging regeneration differed in a number of ways for some forest groups.

Species frequency and forest attributes (n = 50)

The present study found *Coprosma quadrifida*, to be significantly more common in logging than wildfire regeneration. Ough (2001) found the frequency of *Coprosma quadrifida* was higher in logged sites (69%) than wildfire sites (45%), yet the difference was not significant. The vascular species, *Nematolepis squamea* ssp. *squamea*, *Monotoca glauca* and *Hymenophyllum peltatum* in this study were more frequent in wildfire than logging regeneration, although the first two of these species were marginally so. Hickey (1994) found *Hymenophyllum peltatum* to be affected by logging and *Nematolepis squamea* ssp. *squamea* and *Monotoca glauca* to be equally affected by logging and wildfire. The greater cover of above ground substrates in wildfire than logged forests in the present study may explain the greater frequency of *H. peltatum* in wildfire forest. Ough (2001) stated that "ferns...are very rarely seen on burnt logs in logging coupes, even after twenty years". Above ground substrates such as logs and stumps are not subject to turbation by birds or small mammals and rotting logs allow vascular plant roots to penetrate through moss, bark, and topsoil (Kirkpatrick 1997; McKenny and Kirkpatrick 1999). Hickey (1994) also described significant differences in frequency between logged and wildfire regeneration for other common filmy ferns, especially *Hymenophyllyum rarum* which is abundant in old growth mixed forest. Differences between Hickey (1994) and the present study may be a consequence of different sampling methods. Hickey (1994) used mean species frequency data per site yet the present study used pooled data therefore the presence of a species was scored

equally whether or not it was scarce or common. Despite these differences in resolution, for filmy ferns, similar negative affects by clear fell and burning were found.

In the present study, some moss species were more common only in logging than wildfire regeneration, and some liverwort species were more common only in wildfire than logging regeneration. There is little scientific research regarding the ecology and reproductive biology of individual bryophyte species in forests of Australia, with only taxonomic references, field guides and general knowledge able to assist explanations of species responses to disturbance (Scott *et al.* 1976; Scott 1985; Scott 1994; Jarman and Fuhrer 1995). The differences in recolonisation indicate that for some liverwort and moss species, wildfire and clearfell logging disturbance events are not the same. Fire intensity largely determines the nature of bryophyte recolonisation (Southorn 1976). If fire intensity varies, species and substrates may survive in local refugia. In comparison, high intensity burns such as those commonly practiced in logging coupes, may destroy substrates and limit colonisation options for particular bryophyte species. The present study, found substrate cover was higher in forest disturbed by wildfire, possibly creating local refugia for bryophytes species. In boreal forests, liverworts found missing from logged forest were found in older forest, particularly on woody substrates absent from logged forest (Söderström 1988a; Rambo and Muir 1998a; Vellak and Paal 1999). However these studies in boreal forests included areas in which logging had occurred more than once. Given that forest in the present study has only experienced one logging event, and the cover of substrates is significantly less in clearfell logged forest than wildfire forest, a second rotation event (in ~ 40 years from present) may negatively impact on recolonisation of bryophytes into a clearfell area. Fennoscandian studies have shown long-term forest management practices that do not allow for the recruitment of coarse woody debris and large old living and dead trees place non-vascular plants at risk (Gustafsson and Hallingback 1988; Söderström *et al.* 1992).

The present study found a number of 'biological legacies ' (Franklin 1990) in wildfire regeneration, for example dead trees and total above ground substrate cover, are less in logging regeneration. Wildfire and windstorms are the major natural disturbances in eucalypt forests (Lindenmayer and Franklin 1997). The greater percentage cover of rocks in wildfire than logging sites may be due to windstorms throwing over dead trees and exposing rocks that are usually beneath the soil surface.

Although the percentage frequency of *Nothofagus cunninghamii* did not differ between logging and wildfire regeneration (n = 50), basal area of *N. cunninghamii* was significantly greater in logging regeneration than wildfire regeneration. Both Hickey (1994) and Ough (2001) found no difference in frequency of *N. cunninghamii* between clearfell and wildfire events. Fire is thought to be a controlling factor in the distribution of *N. cunninghamii* (Howard and Ashton 1973). *N. cunninghamii* may coppice if fire intensity is low however, if fire intensity is high, *N. cunninghamii* individuals and stored seed are killed and regeneration is mainly dependent on dispersed seed (Hickey *et al.* 1982). *N. cunninghamii* has a limited dispersal range (Howard and Ashton 1973; Hickey *et al.* 1982). High intensity burns in clearfell operations usually destroy all residual mature trees. A greater basal area of *N. cunninghamii* in logged areas compared to wildfire sites is perhaps a result of an available seed source from surrounding forest and favourable site conditions. Successful establishment has been shown to occur from seed dispersal outside of wildfire sites but is dependent on mast seeding events soon after a fire to allow mass recruitment and reduce competitive effects from sclerophyllous or coppicing species (Hill and Read 1984; Barker 1991). Another possibility is that wildfire areas were burnt at a greater fire intensity than logging regeneration burns; "maximum fire intensities are most likely to occur during fires burning with strong wind in dry heavy fuels on steep slopes" (Gill 1997) and some wildfire areas in the present study were on steeper slopes than logging areas (Table 6.1).

If intervals between logging events were to decrease in mixed forests from 90 years, because of its poor dispersal abilities, the frequency of *N. cunninghamii* and other rainforest species is likely to be reduced in silvicultural areas (Cunningham and Cremer 1965). A mosaic of old and young forests in a landscape, or alternative methods to clearfell and burn logging such as 'understorey islands' (Ough and Murphy 1998; Hickey *et al.* 2001) may assist recolonisation of *N. cunninghamii*. Retention of streamside reserves and habitat strips may also assist in the retention of rainforest species. *N. cunninghamii* is an important substrate for bryophytes, lichens and vascular epiphytes (Ashton and McCrae 1970; Milne and Louwhoff 1999). The species composition of bryophytes on *N. cunninghamii* between old growth forest and regrowth forest is different (see Chapter 5). Loss of such a unique substrate would negatively affect biodiversity in mixed forests.

Southern, Northern, and Central forest – species composition and forest attributes

Southern forest

The main eucalypt dominant of sites sampled in the southern and northern forest is *Eucalyptus obliqua*. There are no environmental reasons to imply that the wildfire areas sampled are different from logging areas, in the Southern forest. Therefore there is no reason to doubt a lack of significant difference in species composition for vascular plants and bryophyte species between logging and wildfire regeneration. There is also a lack of significant difference for substrate cover and basal area of vascular species between wildfire and logging areas sampled.

Northern forest

There is no significant difference in species composition for vascular plants between logging and wildfire regeneration. Environmental variables also explain little variation in vascular species composition. Environmental differences were found between wildfire and logging sites. Analyses using generalised linear models found differences in bryophyte species composition between groups of logging and wildfire regeneration sites were due to slight differences in environment and not the relative response of bryophyte species to disturbance by logging or wildfire.

The basal area of *Dicksonia antarctica* (Treefern) was significantly greater in logging than wildfire sites. Ough (2001) found treeferns in *E. regnans* dominated wet forest to be significantly more frequent in wildfire than logging regeneration. In the present study, there was no significant difference in treefern basal area between wildfire and logging regeneration in Southern or Central forest or in all forest sites. Lower intensity burns in logged sites than wildfire sites may explain the higher basal area of treeferns for logged sites of northern latitudes. Alternatively, coverage by slash or damage by machinery may not have been sufficient enough to cause demise (cf. Ough and Murphy 1996).

Central forest

Unlike other regions, *Eucalyptus regnans* dominates the regeneration in the Central forest. It usually occurs as pure stands in high rainfall areas on fertile soil (Kirkpatrick *et al.* 1988). *E. regnans* has most likely been eradicated from some areas of Tasmania because of its high sensitivity to fire: it has no lignotuber, is unable to vegetatively reproduce and because it depends on sexual reproduction, where fire events are frequent

seed supplies may be eliminated (Kirkpatrick *et al.* 1988; Ashton and Attiwill 1994). Significant differences in both bryophyte and vascular species composition were found between logging and wildfire regeneration in *E. regnans* dominated forest. In the present study, analyses using generalised linear models found differences in bryophyte species composition between groups of logging and wildfire regeneration sites were due to mean annual temperature and the response of bryophyte species to logging and wildfire. This result complements those of other studies that have found differences between clearfell and wildfire regeneration in *E. regnans* forest for vascular plants, fauna and forest structure (Lindenmayer *et al.* 1990b; Lindenmayer *et al.* 1999; Ough 2001; Lindenmayer and McCarthy 2002). Similarly, in northwestern Ontario, differences in species composition between clear-cut and wildfire forest for herbaceous plants (vascular and non-vascular) were found (Johnston and Elliot 1996).

Bryophyte species that were found more frequently in clearfell logging than wildfire areas are generally epiphytic, for example, *Neckera pennata*, *Weymouthia cochlearifolia*, *Calyptopogon mnioides*, *Macromitrium archeri*, and *Frullania clavata*. The basal area of vascular plant species was greater in logged forest, perhaps explaining the greater frequency of these epiphytic species in logged areas. The differences in basal area of vascular species between the disturbed forest types may be a consequence of seed availability, seed dispersal, seed storage and competition or inhibition of seed germination by bryophytes or other vascular species after burning (Hill and Read 1984). The supply of propagules into a logged area is expected to be high, due to the small area, whereas in areas burnt by wildfire supply is more variable because of the patchiness of wildfire. Following regeneration burning after logging, eucalypt species are sown, whereas propagule supply into a wildfire area by species such as *E. regnans* and *N. cunninghamii* (Hickey 1982; Hill and Read 1984), which are mast seed producers with poorly dispersed seed, may be more variable. Logging and wildfire events sampled did not all occur in the same years, therefore life history characteristics may explain differences in basal area of vascular species between the disturbed forest types.

Availability of substrates may explain differences observed in bryophyte and vascular plant species composition. There was a higher percentage cover of dead trees, rocks and above ground substrates, in wildfire than clearfell sites. Rocks are suitable substrates for species that also occur on the ground (see Chapter 5; Jarman and Kantvilas 2001b). Dead standing trees not only provide a habitat for many vertebrate

and invertebrate species but when fallen, they provide a substrate for bryophytes (see Chapter 5; Ashton 1986; Lindenmayer *et al.* 1999). The falling of dead trees may explain the greater area of rocks, where upturned roots expose rocks to the ground surface. Dead standing trees also protect the surrounding vegetation from extreme environments (Mount 1969).

Wildfire may destroy, kill or scorch trees, depending on its intensity (Ashton 1981b). In contrast, clearfell operations usually completely fell all standing vegetation. In the 1960's and 1970's different logging methods were employed in different areas of Tasmania (Wood and Kirkpatrick 1984). For example in Southern forests, clearfelling often left seed trees in some areas (Korven-Korpinen and White 1972; Florence 1996), with many of these most likely killed in regeneration burns. The retention of trees in a clearfelled area may be a reason for the lack of difference in bryophyte species composition between logged and wildfire sites for the Southern forests. Compared to live trees, dead or damaged trees have a greater potential to collapse (Lindenmayer *et al.* 1990a) and become coarse woody debris which is an important habitat for many bryophyte species (see Chapter 5; Spies *et al.* 1988; Andersson and Hytteborn 1991; Kruys *et al.* 1999; Lindenmayer *et al.* 1999).

The present study asked the principal question, if species composition of bryophytes and vascular plants differs between disturbance types, is the difference due to the disturbance event or other environmental factors? For the *Eucalyptus regnans* - dominated Central forests aged 40 years after disturbance, disturbance type does appear to influence bryophyte species composition. Current rotation cycles for felling of wet eucalypt forest are 90 years. Given that the cover of substrates in these Central forest is significantly less in clearfell logged forest than wildfire forest, and bryophytes appear to be slow colonisers compared to their vascular counterparts, a second rotation event may negatively impact on recolonisation of bryophytes into a clearfell area. The retention of 'biological legacies' in areas that have been clearfell logged and burnt is likely to assist in the rapid recolonisation of species such as bryophytes and epiphytic ferns.

Chapter Seven

General discussion

The preceding chapters examined relationships between bryophyte species and substrates and investigated what factors influence the richness and composition of bryophytes in wet eucalypt forest of Tasmania. This chapter considers the implications of these results in terms of the reservation of bryophytes and forestry practice.

Wet eucalypt forest compared with other forest ecosystems

Bryophyte ecology in both temperate and boreal forest ecosystems of the northern hemisphere has been well studied, with much research concentrating on boreal forest, for example La Roi and Stringer (1976), Slack (1977), Söderström (1981), Jonsson and Esseen (1990), Lesica *et al.* (1991), Longton (1992), Linder *et al.* (1997), Ohlson *et al.* (1997), Crites and Dale (1998), Jonsson and Esseen (1998), Nguyen-Xuan *et al.* (2000) and Ross-Davis and Frego (2002). Similar bryophyte species are dominant in primary succession following disturbance in both Tasmanian wet eucalypt forest and the boreal forest. These species have similar functions within the different forest ecosystems, for example as they cover the forest floor they retain moisture and actively either prohibit or facilitate germination of other potential colonising species (Cremer and Mount 1965; During and van Tooren 1990). However, bryophytes found in post-primary succession differ between these forest ecosystems. Ground layer bryophytes in Tasmanian wet eucalypt forest have lower cover in comparison to boreal forests. This is mostly because dominant sclerophyllous vascular plants continuously add bark, leaves and woody debris to the litter layer of wet eucalypt forest. This accumulation of litter occasionally either overwhelms bryophytes or is unsuitable for colonisation (Ashton 1986). Many temperate deciduous northern hemisphere forests have sparse growth of bryophytes on the ground due to a much greater litter fall (Longton 1992). In contrast, the ground layer or 'duff' of boreal forest is a carpet of lichens and bryophytes which in old forests can range in cover from 0 – 69% and 0 – 92% for lichens and bryophytes respectively (Pharo and Vitt 2000).

Vascular plants as surrogates for bryophyte species

Much work on Tasmanian bryophytes has been inventory based and aimed towards their conservation (Ratkowsky and Ratkowsky 1982; Ratkowsky 1987; Dalton *et al.* 1991;

Jarman and Kantvilas 1994; Jarman and Kantvilas 1995; Moscal and Kirkpatrick 1995; Jarman and Kantvilas 2001a). Despite this work, a lack of ecological and distributional data on bryophyte species, in comparison to vascular plants, has meant that many bryophytes are simply regarded as 'covered' by surrogate groups such as vascular vegetation communities. With the exception of *Sphagnum* communities (Whinam *et al.* 1989; Whinam *et al.* 2001), there are no management guidelines for the conservation of bryophytes in Tasmanian reserves or on private land. With large amounts of funds being directed toward conservation of vascular plants in forest communities (Commonwealth of Australia and the State of Tasmania 1996), this surrogacy approach to bryophyte conservation has been accepted with little verification (Pharo and Beattie 2001). It is possible that reservation of wet eucalypt forest communities based on economic or surrogate methods may have an impact on the future security of bryophyte species. Chapter 4 has shown that it is possible to reserve most wet eucalypt forest bryophyte species by adequately reserving thirty-three to forty-one sites of wet eucalypt forest. More rare species, such as *Calyptrochaeta brownii, Drepanolejeunea aucklandica* and *Radula retroflexa* (Table 4.2), may not be 'covered' by these sites thus there are limitations in using one taxonomic group as a surrogate for another taxonomic group.

Implications of forestry operations on bryophytes

Continued alteration of native forests by agricultural and forestry practices may affect the conservation and distribution of bryophytes. The conversion of native forest to softwood and/or hardwood plantation is likely to heavily impact upon bryophytes. Fennoscandian studies have shown that large scale clearing and subsequent planting of foreign trees detrimentally affect the bryophyte flora (Gustafsson and Hallingback 1988; Söderström 1988a; Kruys *et al.* 1999). Many epixylic species are now endangered because modern forestry does not allow either the retention of logs or the long intervals between felling that produce mature logs (Söderström *et al.* 1992). Mixed forest has been cleared for agriculture and forestry operations over much of its extent in the northeast and on the northwest coast of Tasmania (McCuaig 1982). Little is known of the bryophyte flora in wet eucalypt forests of northeast Tasmania, where plantation operations are rapidly expanding (Pharo and Blanks 2000; Resource Planning and Development Commission 2002). Since 1996, there has been a 33.3% (48,800 ha) increase in plantation areas either on previously cleared agricultural land or in cleared

native forest of Tasmania (Resource Planning and Development Commission 2002). These plantations are monocultures of *Eucalyptus nitens* and *Pinus* species (both of which are not native to Tasmania) and *Eucalyptus globulus*. Given the past detrimental effects of clearing on bryophyte species richness and abundance (Scott *et al.* 1997), the creation of extensive monocultures under current modern forestry practice could threaten some bryophyte species.

The current harvesting rotation of wet eucalypt forest is between 80 and 100 years (Whiteley 1999). In terms of the vascular flora, current methods and rotation lengths may be sufficient for the regeneration of sclerophyllous understorey species (Hickey 1994), but rainforest species are likely to decline in abundance and some may disappear (Gilbert 1959; Hill and Read 1984). The main effect of current rotation cycles on bryophyte species in wet eucalypt forest is likely to be habitat/substrate removal. Clearfelling removes overstorey and understorey species, reducing the subsequent recruitment of coarse woody debris. The frequency of rotation events are insufficient to allow for large trees to grow, fall to the forest floor and decay. Rainforest species such as *Nothofagus cunninghamii* and *Atherosperma moschatum*, which provide microhabitats for distinct assemblages of bryophyte species (Chapter 5), will not develop into large individuals within such short harvesting rotations. Streamside reserves, wildfire habitat strips and buffer zones around logged areas are habitats where bryophytes and old individuals of rainforest vascular species can persist (Pharo and Blanks 2000). However, considering that we know little of bryophyte species dispersal in wet eucalypt forest, we can only speculate how segregation in the landscape and a decrease in substrates will affect bryophyte species.

In the present study, approximately four decades after logging and wildfire disturbance in *Eucalyptus regnans* dominated forest, a comparison of disturbance types found substantial differences in bryophyte species composition. The practice of clearfell and burn harvesting in *Eucalyptus regnans* forest alters the natural succession of bryophytes. The time since clearfelling and burning in the forests surveyed is approximately half that of a standard rotation. Further work is needed to investigate if bryophyte species composition between logging and wildfire disturbed *Eucalyptus regnans* forests would be more similar with longer rotations.

Reservation and conservation of bryophytes

The Tasmanian Regional Forest Agreement (RFA) (Commonwealth of Australia and the State of Tasmania 1996), concluded in the late 1990's, gave rise to a substantially enlarged forest reserve system. Before the RFA process, the economically valuable *Eucalyptus regnans* and *Eucalyptus obliqua* wet eucalypt forest communities were poorly represented in the reserve system, whereas non-economically valuable communities (those less attractive for agricultural/forestry development) were substantially reserved (Mendel and Kirkpatrick 2002). Despite a large increase in the amount of wet eucalypt forest reserved, the represented area was still substantially less than that for non-economically valuable communities. Many wet eucalypt forest reserves are patchily distributed or situated adjacent to already reserved areas on poor quality/fertility sites in remote locations.

The Regional Forest Agreement process aimed to ensure that 'where practicable and possible' the aesthetic, wilderness, old growth and biodiversity values of Australia's forests were sufficiently reserved and managed, while socio-economic standards were accommodated (Commonwealth of Australia and the State of Tasmania 1996). Under the Agreement, logging in statutory secure and insecure reserves is prohibited for the next 20 years. However, it is unclear what happens to insecure reserves after this time.

Eight bryophyte species in the present study are recorded as unreserved in the state (Moscal *et al.* 1997). Two species, *Calyptrochaeta brownii* and *Marsupidium setulosum* were found by the present research in both unreserved and reserved (one site) old growth mixed forest. Three species, *Daltonia splachnoides, Campylopus flindersii* and *Macromitrium ligulaefolium* were found in old growth mixed forest and forest regenerating after logging (31 – 67 years). The former two species were also found in wildfire regenerating forest (31 – 67 years), with *Campylopus flindersii* more common in logging than wildfire regeneration. *Hampeella alaris* was found in both forest regenerating after logging (1 – 18 years) and old growth mixed forest. Finally, *Heteroscyphus argutus* and *Radula retroflexa* were found in forest regenerating after wildfire and logging (31 – 67 years) respectively. These eight species are listed either as vulnerable, critically endangered, endangered or data deficient by Moscal *et al.* (1997). The distribution and ecology of these species needs to be the subject of further investigation.

Implications for forest management

With the RFA process reserving more wet eucalypt forest, there has since been a development of 'more efficient' forestry practices (Bauhus 1999). These include allocation of large areas for plantation forest and the more extensive removal of 'waste wood' for logging products or power generation plants (Forestry Tasmania 2002; Resource Planning and Development Commission 2002).

In response to concerns regarding the conservation of biodiversity and harvesting methods, many authors have made suggestions for the provision and protection of substrates that will enable the persistence of many components of biodiversity in managed areas (Lindenmayer *et al.* 1990; Hickey 1994; Ough and Murphy 1996; Franklin *et al.* 1997; Ough and Murphy 1998; Nicholson 1999; Bassett *et al.* 2000; Ough 2001; Lindenmayer and McCarthy 2002). Some suggestions of particular relevance to the conservation of bryophytes in wet eucalypt forest include the preservation of patches of understorey vegetation, retention of living and dead trees, the protection of existing logs and recruitment of new ones, larger retained wildfire strips, use of a broader variety of logging practices, and substantially longer rotation periods (150 - 200 years) to allow for the development of substrates and establishment of slow colonising species. Some of these methods are currently under development and review in Tasmania (Hickey *et al.* 2001). Elsewhere, other potential methods, such as the transplantation of bryophytes onto retained trees, have been successful (Hazell and Gustafsson 1999).

Modifications to silvicultural systems, such as retention of substrates and long rotations will impact the value of timber harvested from wet eucalypt forests. Franklin *et al.* (1997) argue that a system of 'variable retention', is an ecologically and economically better alternative to long rotations. Similarly, Lindenmayer and McCarthy (2002) suggest that aggregation of different vegetation retention patterns might assist in alleviating cost and safety issues. Variable retention is considered to be incompatible with high intensity burning, which delivers cost effective successful eucalypt regeneration. Although alternative methods may prove more expensive, concurrent use of clearfell, burn and harvesting methods adjacent to natural regenerative areas in the landscape, may provide a better balance between natural and human disturbance.

Bryophytes play an important role in the function and structure of wet eucalypt forest in Tasmania. To conserve biodiversity in wet eucalypt forest, reservation should not just aim for the conservation of a taxonomic group or an individual species, but conservation of the whole ecosystem. There is the need to collect data on likely rare and threatened bryophyte species including distribution, population size, substrate ecology and substrate availability. Collection of such data will assist attempts to protect threatened species. Some understanding of the mechanisms that underlie the bryophyte compositional differences between *Eucalyptus regnans* and *E. obliqua* forests and their relative response to logging and wildfire would be desirable.

Increased knowledge into the biology and ecology of bryophytes in wet eucalypt forest will further develop our understanding of the effects of forestry practices. Resource management can then make more informed decisions on whether or not species can endure the impacts of human disturbance. Finally, for conservation of bryophytes in wet eucalypt forest to be successful, knowledge and awareness of bryophytes among non-bryologists, forest planners, and the forestry industry must be increased.

Chapter Eight

Appendices

Appendix 8.1. Site information for 105 sites.

Site No	Region	Forest type	Year of disturbance	Latitude	Longitude	Altitude (m)	Slope (°)	Aspect (°)	pH	Total Nitrogen (% dry weight)	Phosphorus (ppm)	% Canopy cover	Number of substrates /site	Geology	Mean annual temperature (°C)	Mean annual rainfall (mm)	Rainfall of the driest month (mm)	Vascular species richness	Moss species richness	Liverwort species richness
1	Southern	Old growth	n/a	43.053275	146 704316	363	8 0	325 0	5 0	0 26	3.25	77.11	20	igneous	9.8	1354	66	25	24	49
2	Southern	Logging	1998	43 052824	146 703823	363	7 0	331.7	6 0	0.20	4.01	0 30	7	igneous	9.8	1354	66	21	6	4
3	Southern	Logging	1992	43.016667	146 641111	467	9.0	58.3	5 0	0.14	2 53	35 12	6	siliceous	9.8	1354	66	16	17	11
4	Southern	Old growth	n/a	43 016389	146 641111	467	13 0	81 7	4.5	0 23	18 28	83.62	12	siliceous	9.8	1354	66	20	33	58
5	Northern	Old growth	n/a	41 093777	144 879388	53	2.3	90.0	5 0	0.20	10 95	85 46	14	siliceous	11 8	1523	63	19	22	31
6	Northern	Wildfire	1966	41.096238	145 001947	177	9.7	190 0	5 5	0.24	2 45	92.34	12	igneous	11.5	1559	65	19	28	36
7	Northern	Logging	1998	41 283913	145 122923	337	5.3	195 0	6 0	0.21	13 73	4 46	8	siliceous	10	2104	94	9	9	4
8	Northern	Old growth	n/a	41 283913	145 122923	340	4 7	313 3	4 0	0 23	26 96	88.14	17	siliceous	10	2104	94	17	18	50
9	Northern	Logging	1998	41 338255	145 054199	257	12.3	253.3	5 5	0 17	11 36	0 00	6	siliceous	10 8	1941	85	11	5	1
10	Northern	Wildfire	1966	41 094145	145 000700	175	7.3	203 3	6 0	0.29	3 65	79 75	12	igneous	11.5	1559	65	22	21	23
11	Northern	Logging	1962	41 043074	144 870071	73	8 3	220 0	5.5	0 22	7 82	83 56	13	siliceous	12 1	1347	55	18	19	25
12	Northern	Logging	1962	41.038922	144 864733	105	2.0	105.0	5 0	0 32	10 86	88 35	16	siliceous	12 1	1347	55	17	21	32
13	Northern	Logging	1995	40.971653	144 975407	107	3 0	240.0	6 0	0.22	9 41	0 00	6	siliceous	12 1	1248	51	18	18	10
14	Northern	Logging	1995	41.113435	145 091821	150	5.3	230 0	4 0	0.30	33.66	22 62	5	siliceous	11.5	1559	65	16	16	10
15	Northern	Logging	1992	41 071944	145 272500	137	12 3	108.3	5 5	0 19	8 08	8 11	5	siliceous	11 5	1489	61	11	8	12
16	Northern	Wildfire	1962	41 057340	145 187928	150	11 0	166 7	3.5	0 44	16 87	87 54	12	siliceous	11 5	1457	61	21	20	24
17	Northern	Logging	1992	41 209899	144.766150	100	2 0	253 3	6 0	0.33	2.39	26 69	6	siliceous	11 5	1668	70	20	12	6
18	Northern	Old growth	n/a	41 209179	144.766174	100	2 0	263 3	6.0	0 42	2 04	57.43	13	siliceous	11.5	1668	70	22	26	34
19	Northern	Old growth	n/a	41.208458	144.775502	123	7 0	171 7	6 0	0 62	2 94	93 38	9	siliceous	11 5	1668	70	17	28	33
20	Northern	Wildfire	1995	41 208481	144 776694	123	6 7	160.0	5.5	0.35	5.99	5 13	9	siliceous	11 5	1668	70	17	18	15
21	Northern	Old growth	n/a	41 159605	144 958309	190	4 3	168 3	5 5	0.42	1 83	72 89	9	igneous	11.8	1523	63	16	25	37
22	Northern	Old growth	n/a	41 159140	144 957489	183	3 3	193 3	6.0	0 31	3.86	97 21	13	igneous	11 8	1523	63	18	28	44
23	Northern	Old growth	n/a	41 121414	144 989033	163	4 3	113 3	5.5	0 33	11.15	92 01	7	siliceous	11 5	1559	65	11	24	38
24	Northern	Old growth	n/a	41 121808	144 990927	170	9 7	220 0	5 5	0 32	10 16	91 99	7	siliceous	11.5	1559	65	16	27	32
25	Northern	Old growth	n/a	41.125291	144 994395	177	23.3	250 0	6 0	0 28	5 72	95 81	12	siliceous	11.5	1559	65	15	28	35
26	Northern	Wildfire	1966	41 172780	145 085569	143	5 3	138 3	4 5	0 47	88.98	90 08	13	siliceous	11.5	1559	65	19	22	32
27	Northern	Wildfire	1966	41.171711	145.086316	142	5.0	116 7	4.5	0.68	117.33	85 39	14	siliceous	11.5	1559	65	18	22	23
28	Northern	Old growth	n/a	41 124481	145 010024	168	10 7	130 0	5.5	0.19	3.62	81 82	11	igneous	11 5	1559	65	16	28	30
29	Northern	Old growth	n/a	41 160382	144 951372	123	10 7	113 3	4.5	0 35	6.22	83.06	9	igneous	11.8	1523	63	13	29	28
30	Southern	Old growth	n/a	43 020020	146 662135	277	14 7	230 0	5 5	0 19	2 30	79 26	14	siliceous	9 8	1354	66	14	19	54
31	Southern	Logging	1983	43 020453	146 656364	337	8.3	170 0	6 0	0.17	3 80	56.86	7	siliceous	9 8	1354	66	13	22	12
32	Southern	Old growth	n/a	43.100247	146 726701	53	2.0	73.3	5 5	0 35	6 73	93 16	17	siliceous	9 8	1398	68	22	32	41
33	Southern	Wildfire	1934/1898	43 096270	146 654712	98	4 3	178 3	5 5	0.21	6 93	76 71	22	siliceous	9 8	1398	68	31	36	43
34	Southern	Old growth	n/a	43 240138	146 953197	277	9 0	173 3	5 5	0 18	6 30	82 43	20	siliceous	10 6	1147	61	25	36	44
35	Southern	Logging	1993	43 228108	146.879320	647	1.7	55 0	5 5	0.26	2.72	46 46	5	igneous	10 6	1147	61	27	8	9

Site No	Region	Forest type	Year of disturbance	Latitude	Longitude	Altitude (m)	Slope (°)	Aspect (°)	pH	Total Nitrogen (% dry weight)	Phosphorus (ppm)	% Canopy cover	Number of substrates /site	Geology	Mean annual temperature (°C)	Mean annual rainfall (mm)	Rainfall of the driest month (mm)	Vascular species richness	Moss species richness	Liverwort species richness
36	Southern	Old growth	n/a	43 240950	146 850596	487	25 7	75.3	4 0	0.70	9.91	85 46	13	igneous	8 6	1534	81	22	46	64
37	Southern	Logging	1963	43.245809	146 847751	418	6 3	160.0	5.0	0 31	1 96	76.74	15	igneous	8 6	1534	81	21	17	31
38	Southern	Logging	1963	43.248477	146 898373	527	5 7	233.3	5.0	0 43	14 18	73 74	15	igneous	10 6	1147	61	21	45	44
39	Southern	Old growth	n/a	43.197912	146 795314	407	15.3	263.3	5 0	0.20	8.29	88.67	19	igneous	8 6	1534	81	24	26	56
40	Southern	Old growth	n/a	43.077622	146.717466	233	19 0	18 3	6.5	0 15	3 02	87 78	15	igneous	9 8	1354	66	16	29	48
41	Southern	Logging	1996	43 090164	146 660275	357	3 3	145 0	6 5	0 09	4 12	0 00	4	siliceous	9 8	1398	68	11	9	4
42	Southern	Logging	1966	43.117115	146 782186	220	14.7	246 7	6 0	0 16	4 72	86 27	17	igneous	10.3	1184	59	19	34	26
43	Southern	Logging	1967	43 106696	146 796602	147	9.3	108 3	5 5	0 33	4 02	85.16	13	igneous	10 3	1184	59	19	38	25
44	Southern	Logging	1961	43 202310	146.787299	457	6 3	116 7	5 5	0.27	2.09	46 63	10	igneous	8.6	1534	81	20	20	32
45	Southern	Logging	1966	43 176626	146 776684	367	4 7	100 0	5 5	0 29	3 25	71 63	16	igneous	8 6	1534	81	19	22	22
46	Southern	Wildfire	1966	43 163452	146 811544	207	15 0	230 0	6.0	0 12	4 93	73 55	17	igneous	10.3	1184	59	23	27	35
47	Northern	Logging	1966	40 991804	145.272584	187	5 7	260 0	6 0	0 27	2 23	84 78	13	siliceous	11.8	1359	55	25	26	35
48	Northern	Old growth	n/a	41 640436	144 942631	40	2.7	180 0	4 0	0 25	37 04	84 22	12	siliceous	12 1	1347	55	23	24	35
49	Northern	Old growth	n/a	41.038800	144.932070	40	4 3	266 7	3.5	1 07	108 05	81 17	15	siliceous	12.1	1347	55	21	26	41
50	Northern	Old growth	n/a	41 101602	145 156108	183	3 3	100 0	5 0	0 37	29 47	88 17	10	siliceous	11.3	1578	66	18	26	29
51	Northern	Old growth	n/a	41 103757	145 167003	180	1.3	150 0	4 5	0.74	32 32	89 09	12	siliceous	11 3	1578	66	22	29	28
52	Northern	Logging	1964	41.039394	144 861030	60	2.0	216 7	4 0	0 29	32 64	89 77	15	siliceous	12.1	1347	55	20	22	32
53	Northern	Logging	1969	41 082348	144 909515	135	1 3	243 3	5 5	0 27	18 53	74 74	14	siliceous	11 8	1523	63	19	18	28
54	Northern	Wildfire	1961	41.239719	145 108317	240	9 3	279 3	4 5	0.39	20 97	76 46	23	siliceous	10 5	1888	83	25	22	29
55	Northern	Wildfire	1961	41 240459	145 109489	247	8.0	98 3	4 0	0.37	18 11	76 49	16	siliceous	10 5	1888	83	23	23	33
56	Northern	Logging	1962	41 029071	144 862910	105	3.3	80 0	5 5	0 25	17 30	82 13	13	siliceous	12 1	1347	55	15	22	28
57	Northern	Logging	1962	41 039912	144 859824	70	5 0	158.3	4 5	0 41	21 92	81 79	19	siliceous	12 1	1347	55	21	20	29
58	Northern	Logging	1962	41 042607	144 869135	75	10 3	248.3	6 0	0 22	14 99	80 42	16	siliceous	12 1	1347	55	14	23	29
59	Southern	Wildfire	1934	43 093520	146 639000	162	5 3	95 0	4 5	0 13	6 17	61 86	15	siliceous	9 8	1398	68	17	18	16
60	Southern	Wildfire	1967	43 111944	146 811944	95	7 7	121.7	5 5	0 28	5.18	84 09	15	siliceous	10 3	1184	59	15	40	31
61	Southern	Logging	1967	43 103056	146 803056	90	4 0	80 0	6 0	0.61	6 83	85.23	12	siliceous	10 3	1184	59	13	44	27
62	Southern	Wildfire	1966	43 116667	146 783333	173	14 7	90 0	6 0	0 57	5 47	84 87	13	igneous	10.3	1184	59	12	37	23
63	Southern	Logging	1966	43.120833	146 787500	148	11 3	183 3	5 5	0 33	7 04	87 09	12	igneous	10 3	1184	59	19	39	31
64	Central	Old growth	n/a	42.718611	146 510278	485	4.7	176 7	5.0	0 22	14 69	83.83	15	carbonate	8.5	1615	80	14	25	35
65	Central	Old growth	n/a	42 718056	146 512778	485	7 7	160 0	5 5	0 21	5 40	81 05	12	carbonate	6.1	1535	82	13	27	42
66	Central	Logging	1961	42 640556	146.493056	532	9.0	293.3	5 5	0.30	12.80	66 97	15	siliceous	8 5	1615	80	11	25	18
67	Central	Logging	1961	42 676111	146 491111	508	11 3	240 0	5.5	0 29	4 46	61 12	12	siliceous	8 5	1615	80	13	41	15
68	Central	Logging	1961	42 678056	146 493611	573	11.7	280 0	5 5	0 30	12 33	64 90	17	siliceous	8 5	1615	80	18	38	19
69	Central	Old growth	n/a	42 498611	146 439444	395	20 7	146 7	5.5	0 40	6 21	65.00	11	siliceous	8 5	1436	72	19	29	24
70	Central	Old growth	n/a	42 497500	146 438889	415	18 7	136 7	5 5	0 31	6 04	78 40	16	siliceous	8.5	1436	72	18	28	26
71	Central	Logging	1961	42 591667	146 497500	543	14 7	240 0	4 2	0 69	25 98	84 27	11	siliceous	8 6	1524	79	8	32	19
72	Central	Logging	1961	42.593333	146 498889	550	14 3	253 3	4.5	0 99	22.66	84 22	11	siliceous	8 6	1524	79	8	31	16
73	Central	Old growth	n/a	42 600833	146 508611	633	18 3	240 0	6 0	0 36	2 93	79.28	19	siliceous	8 6	1524	79	14	38	39
74	Central	Logging	1961	42.598611	146 492778	450	8.0	230 0	6.0	0.19	3 14	81 29	11	carbonate	8.6	1524	79	14	29	22
75	Central	Logging	1961	42 595000	146.493056	480	8.3	210 0	5.5	0.51	12.96	82 73	12	carbonate	8 6	1524	79	13	39	20
76	Central	Wildfire	1966	42 651944	146 493333	600	17.7	270 0	4.5	0 22	12.86	80.17	13	siliceous	8 5	1615	80	13	26	28
77	Central	Wildfire	1966	42 652778	146.493333	598	20 0	230 0	5.5	0.29	27.56	79 54	15	siliceous	8 5	1615	80	17	25	26
78	Central	Wildfire	1966	42 653056	146 493611	610	22.7	233 3	5 0	0.33	71 77	69 32	14	siliceous	8 5	1615	80	22	27	21

Site No	Region	Forest type	Year of disturbance	Latitude	Longitude	Altitude (m)	Slope (°)	Aspect (°)	pH	Total Nitrogen (% dry weight)	Phosphorus (ppm)	% Canopy cover	Number of substrates /site	Geology	Mean annual temperature (°C)	Mean annual rainfall (mm)	Rainfall of the driest month (mm)	Vascular species richness	Moss species richness	Liverwort species richness
79	Central	Old growth	n/a	42 837222	146 640278	565	4.3	315 0	3 5	0.55	22 77	83.57	12	siliceous	7 5	1486	79	12	32	31
80	Central	Old growth	n/a	42 837222	146 639444	570	8 7	330 0	3 5	0 49	20 04	83 03	14	siliceous	7.5	1486	79	11	23	33
81	Central	Wildfire	1966	42.835000	146.662222	600	14.7	283 3	4 0	0.23	20 17	34 93	8	siliceous	7 5	1486	79	16	13	24
82	Central	Wildfire	1966	42 833889	146 662778	610	16 7	280 0	4 0	0 19	18 62	43 03	11	siliceous	7.5	1486	79	19	14	21
83	Central	Wildfire	1966	42.834722	146.663611	640	11.0	268 3	4 5	0.11	10.37	49.93	12	siliceous	7 5	1486	79	15	15	18
84	Central	Logging	1966	42 836667	146 630556	525	5 0	295 0	5 0	0.41	25 88	59.29	14	siliceous	8.3	1614	76	15	22	15
85	Central	Old growth	n/a	42.836944	146 641389	565	7 3	350.0	5 5	0 33	10 27	77 59	10	siliceous	7.5	1486	79	11	31	31
86	Central	Wildfire	1966	42.658611	146.496111	660	19.3	230.0	5 5	0 32	5 22	57 83	12	siliceous	8 5	1615	80	20	36	30
87	Central	Wildfire	1966	42 657778	146 496389	660	21 7	223.3	6 5	0 32	1 51	61 63	14	siliceous	8.5	1615	80	13	43	35
88	Central	Logging	1963	42 830833	146 626944	500	1 3	316 7	5 0	0 58	6 28	87.94	16	siliceous	8.3	1614	76	11	29	28
89	Central	Logging	1963	42 830833	146 625556	500	1.0	156.7	4 5	0.36	5 57	89 93	16	siliceous	8 3	1614	76	9	29	19
90	Central	Old growth	n/a	42.830000	146 635278	500	3 0	73.3	5 0	0 61	40 22	81 32	12	siliceous	7.5	1486	79	14	29	37
91	Central	Old growth	n/a	42.506944	146 459167	430	12.7	266.7	5 5	0 46	2 77	81 13	16	siliceous	8 5	1436	72	10	26	24
92	Southern	Wildfire	1966	43 191667	146 796944	550	22 3	230 0	6 0	0 18	4 27	78.22	11	igneous	8 6	1534	81	15	28	30
93	Southern	Wildfire	1966	43.184722	146 798056	490	22 7	276 7	5 5	0 20	7 58	76 62	13	igneous	8.6	1534	81	11	23	23
94	Southern	Wildfire	1966	43 181667	146 795000	350	20 3	261 7	5 0	0 29	3.44	81 26	13	igneous	8 6	1534	81	10	24	30
95	Southern	Wildfire	1966	43.181111	146 794444	350	26.0	266 7	6 0	0.25	3 82	81 32	10	igneous	8 6	1534	81	12	27	36
96	Southern	Wildfire	1966	43 104167	146 786111	360	22.7	100 0	6.0	0 38	9 11	88 38	13	igneous	10.3	1184	59	18	30	35
97	Southern	Wildfire	1966	43 104444	146 786667	340	9 7	120 0	6 0	0 51	3 11	82 72	15	igneous	10 3	1184	59	20	32	51
98	Southern	Wildfire	1934	43 119444	146 757222	340	12 7	240 0	4.5	0 02	6 45	81 82	12	siliceous	10 3	1184	59	13	15	18
99	Southern	Wildfire	1934	43 089444	146 642222	183	14 3	180.0	3 5	0 24	8 71	81.59	18	siliceous	9 8	1398	68	15	20	17
100	Central	Logging	1993	42 466111	146.474444	633	13 0	40 0	6 5	0 36	0 88	45 39	6	igneous	8.5	1436	72	16	24	5
101	Central	Logging	1996	42 467222	146.473889	640	12.0	103.3	5 5	0 32	0.99	42 06	6	igneous	8 5	1436	72	14	10	4
102	Central	Logging	1998	42 457500	146.473333	573	6.0	106.7	6 5	0 21	1 34	0 00	7	igneous	8 5	1436	72	12	23	7
103	Central	Logging	1998	42.455556	146.474722	563	16 0	105.0	6 5	0.59	1 84	0.00	6	igneous	8 5	1436	72	13	11	3
104	Central	Logging	1998	42 816944	146 963611	573	9 7	310 0	4.5	0 08	11 08	0 00	5	igneous	8 3	1104	64	12	4	3
105	Central	Logging	1998	42 831389	146 953611	577	4 7	303 3	4 0	0.13	6 10	33 02	5	igneous	8 3	1104	64	16	6	5

Appendix 8.2. Site characteristics for 105 sites. a = age class a (1 – 18 years), b = age class b (31 – 67 years), c = age class c (> 110 years).

					% Cover of above ground substrates										Basal area (m^2 ha^{-1})				
Site No	Age class	*Eucalyptus* species dominant and co-dominant	Vascular communities	Bryophyte communities	Log	Fallen branch	Tree	Roots	Stump	Rock	*Dicksonia antarctica* alive/vertical	*Dicksonia antarctica* dead/horizontal	Dead tree	Upturned tree base	**Total**	Dead trees	Rainforest species	*Eucalyptus* species	*Dicksonia antarctica*	**Total**
1	c	*E. obliqua*	A	L	7 93	1 33	6.36	0 00	0 00	1 13	0 00	0 00	0.00	0 00	**16.76**	0 00	21.33	5 33	0 00	**26.67**
2	a	*E obliqua*	B	T	16 13	0 91	0 17	0 00	0.00	5 67	0 00	0 00	0.00	0 80	**23.68**	0 00	0 00	0.00	0 00	**0.00**
3	a	*E obliqua*	C	U	3.53	0.49	0 49	0 00	5.73	0.20	0 00	0 00	0.00	2 67	**13.12**	0.00	1 33	10 00	0 00	**13.33**
4	c	*E. obliqua*	I	N	22.87	1.65	0 67	0.89	0.00	0 00	0.00	0 00	0 13	0 00	**26.21**	2.00	23.33	1 33	7 33	**34.00**
5	c	*E. obliqua*	J	O	16 67	0 49	2.36	0 35	0 93	0 00	0 13	0.00	0 27	0 00	**21.20**	0.67	17 33	16 67	12 00	**47.33**
6	b	*E. obliqua*	J	O	6 40	0 36	1.12	1 93	1 60	0 00	0 00	0.00	0 00	0 00	**11.41**	0.00	34 67	11 33	3 33	**49.33**
7	a	*E obliqua*	C	T	11 47	0.67	0 53	0 13	5 80	0.40	0 00	0 00	0 00	1 27	**20.27**	4 67	0.00	1 33	0 00	**6.00**
8	c	*E obliqua*	I	L	6 00	1 83	4.60	0 29	1 33	0 00	0 00	0 00	0 27	0 40	**14.72**	0 00	20.67	8 67	0 00	**30.67**
9	a	*E obliqua*	B	T	10 73	0.33	0 00	0 00	4 13	0.00	0 00	0 00	0 00	0 00	**15.20**	1.33	0 00	0 67	0 00	**2.00**
10	b	*E obliqua*	D	O	11 20	0.48	0 40	0 00	0 67	0 00	0 00	0.00	0 13	0 00	**12.88**	0 00	8 67	29 33	0 00	**46.00**
11	b	*E. obliqua, E brookeriana*	D	O	10 00	0 49	1.19	0.00	0 00	0 00	0 00	0 00	0.00	0 00	**11.68**	0 00	15.33	34 00	8 67	**58.00**
12	b	*E. obliqua, E brookeriana*	J	O	7 27	0 67	0.47	0 00	2 27	0 00	0 00	0.00	0 00	2 67	**13.33**	0 00	4 67	17.33	1 33	**38.00**
13	a	*E obliqua*	D	V	12.40	0 83	0.07	0.00	5 33	0 00	0 00	0 40	0 00	3.20	**22.23**	0 00	0.00	0 00	0 00	**0.00**
14	a	*E obliqua*	C	U	7.27	0.83	0 00	0.00	4 93	0 00	0 00	0 00	0 33	0.40	**13.76**	0 00	0.00	1 33	0 00	**1.33**
15	a	*E obliqua*	B	T	5 13	0 00	0 13	0.00	4 80	0 00	0 00	0.00	0 00	0.00	**10.07**	0 00	0.00	6 67	0 00	**6.67**
16	b	*E. obliqua, E brookeriana*	D	M	12.67	0.93	0 56	0.00	1 33	0 00	0 00	0.00	0 47	0 00	**15.96**	0 00	1.33	13 34	0.00	**35.36**
17	a	*E obliqua*	D	V	3 53	0 40	0 09	0 00	7 33	0 00	0 40	0 00	0 00	0 00	**11.76**	0 00	0 00	16 00	0 67	**16.67**
18	c	*E obliqua*	J	O	9 40	1 17	2 27	0 00	0 00	0 00	1 27	0 40	2 13	0.80	**17.44**	0 67	13.33	18 00	18 00	**50.00**
19	c	*E obliqua*	J	O	2 27	1.80	2.90	0 00	0 00	0 00	3.73	6 53	0 00	0.00	**17.23**	0 00	18 00	2 00	35 00	**40.00**
20	a	*E obliqua*	D	V	13 60	2.15	0 67	0 00	0 00	0 00	0 53	0 00	1 60	0.00	**18.55**	16 67	3 33	1 33	12 00	**36.67**
21	c	*E obliqua*	K	O	14.73	1.24	0 53	0 96	2 00	0.00	0 47	0 00	0 00	0.00	**19.93**	0 00	28 67	0 67	9 33	**38.67**
22	c	*E obliqua*	J	O	9 53	1.17	1.00	1 48	2 40	0 00	0.47	0.00	0 00	0.00	**16.05**	1 33	21 33	1.33	6.67	**30.67**
23	c	*E obliqua*	J	O	6 40	1 08	3 40	0.41	0 00	0 00	0 00	0 00	0.00	0 00	**11.29**	0 00	30 67	10 67	0 67	**42.00**
24	c	*E obliqua*	J	O	7 33	1.59	7 07	0 00	0 00	0 00	0 53	0 00	0 00	0 00	**16.52**	0.00	30 00	14 67	4 00	**48.67**
25	c	*E obliqua*	J	O	9 00	1.05	0 73	0 73	4 67	0.27	0 00	0 00	0 00	0 00	**16.45**	0 00	20 67	3 33	12 00	**36.00**
26	b	*E obliqua*	D	M	11 53	1.68	5.03	0 00	1 33	0.00	0 00	0.00	0 00	0 00	**19.57**	0.00	12 67	11 33	0 00	**28.67**
27	b	*E obliqua*	D	M	8 00	2.19	2.80	0 00	0 00	0 00	0 00	0.00	0 00	0 00	**12.99**	0 00	2 67	23 33	0 00	**28.00**
28	c	*E. obliqua*	J	O	6.60	0.89	1.20	0 12	1.33	0 00	1.33	0 00	0 00	2 27	**13.75**	0 00	26 00	4 67	12 67	**44.00**
29	c	*E. obliqua*	I	L	9.33	2.53	3 07	0.75	0 00	0 00	0 00	0.00	0 00	0.00	**15.68**	0 00	28 67	22.67	0 00	**51.33**
30	c	*E obliqua*	A	L	11 73	2.20	4.03	0 73	0 00	0 53	0 00	0 00	0 00	0 40	**19.63**	0 67	31 33	10.67	0 00	**42.67**

					% Cover of above ground substrates										Basal area (m^2 ha^{-1})				
Site No	Age class	*Eucalyptus* species dominant and co-dominant	Vascular communities	Bryophyte communities	Log	Fallen branch	Tree	Roots	Stump	Rock	*Dicksonia antarctica* alive/vertical	*Dicksonia antarctica* dead/horizontal	Dead tree	Upturned tree base	**Total**	Dead trees	Rainforest species	*Eucalyptus* species	*Dicksonia antarctica*	**Total**
31	a	*E obliqua*	C	U	10.27	0 45	1 68	0.00	3 33	2.93	0 00	0.00	3 33	1 33	**23.33**	2.00	0.00	40.67	0 00	**43.33**
32	c	*E. obliqua*	I	P	9 40	1.23	2 23	0.75	0.00	0 00	1 07	0.00	0 00	0 00	**14.67**	0 00	30 67	10 00	6 67	**49.33**
33	b	*E obliqua*	J	P	7.07	2.40	3 53	1 27	0.00	0.00	0.40	0 00	0 13	0 00	**14.80**	5.33	12.67	16 00	24 67	**70.00**
34	c	*E. regnans*	K	P	17 80	2 69	3 16	0 96	0 00	0 00	1 60	1 33	0 00	0 00	**27.55**	0 00	16 67	8.00	14 00	**42.00**
35	a	*E. obliqua*	A	T	10 80	0.33	0 75	0.07	4 00	0 00	0 00	0 00	0 00	0 00	**15.95**	0 00	0 00	8.00	0 00	**8.00**
36	c	*E obliqua*	J	P	9 73	1.45	5 29	2.52	0 00	1.93	1 87	1.73	0 00	0 00	**24.53**	0.00	37.33	3 33	22.00	**62.67**
37	b	*E obliqua*	A	R	13 29	0 89	1 60	0 00	5 07	3 68	0 00	0.00	3 33	1 40	**29.27**	0.67	0 00	14.00	0 00	**27.33**
38	b	*E obliqua*, *E. delegatensis*	E	P	17 40	1 55	5.32	0 13	0 00	1.60	0.00	1 07	0.00	0.00	**27.07**	0 67	3 33	16 67	3 33	**38.67**
39	c	*E. obliqua*	A	N	15 13	2 61	4 15	2 36	0 00	1.73	0.00	0 00	0.00	4 20	**30.19**	0 00	40 67	4 67	0 00	**46.00**
40	c	*E obliqua*	I	N	10 33	3 13	6.81	0 00	0 00	1 47	0 00	0.00	0 00	4 67	**26.41**	0.00	12 00	6 67	0 00	**19.33**
41	a	*E. obliqua*	B	T	13 40	0.00	0 23	0 00	0 53	6 40	0 00	0 00	0 00	0.00	**20.56**	0 00	0 00	2.67	0 00	**2.67**
42	b	*E regnans*, *E obliqua*	E	P	17 87	0 60	2.73	0.00	0 00	1 20	0 00	0.00	1 07	1 07	**24.53**	0 67	0 00	20.67	4 00	**66.67**
43	b	*E regnans*	J	P	8.27	1.55	2 87	0 13	0 00	0 80	1.20	0 93	0 00	2 67	**18.41**	0 00	2 00	11.33	15 33	**53.33**
44	b	*E delegatensis*	A	R	13 67	0.23	2 77	0 00	0 00	3 27	0 00	0 00	0.00	0.00	**19.93**	0.00	4.00	26.00	0 00	**30.67**
45	b	*E delegatensis*	A	R	19.47	0 80	1 93	0 00	3 07	0 67	0 00	0 00	0.00	0.00	**25.93**	0 00	0 67	53 33	1 33	**57.33**
46	b	*E obliqua*, *E regnans*	E	S	10.87	1 20	2 85	0.00	0 80	2 07	0.00	0.00	2 40	4 60	**24.79**	1.33	2 67	48 67	0 00	**63.33**
47	b	*E. obliqua*	J	O	9 93	1.15	4 12	0 07	1 47	0 00	0.00	0 00	2 80	0 00	**19.53**	0 67	3 33	26.67	3 33	**95.33**
48	c	*E obliqua*	J	O	7 20	1.88	4 60	0 00	0 00	0.00	1.07	1.73	0 00	0 00	**16.48**	1.33	20.00	6 67	24 67	**52.67**
49	c	*E obliqua*	I	O	5 33	1.53	6 96	0.83	0 00	0 00	0.00	1 00	0 00	0 00	**15.65**	3 33	26.67	6 00	20 67	**56.67**
50	c	*E obliqua*	J	O	4 40	1.87	13.03	0 47	1.20	0 00	0 40	0 00	0.00	0 00	**21.36**	0.00	16.00	6 00	42.67	**64.67**
51	c	*E. obliqua*	J	O	8 40	1 43	9 33	0 00	0 00	0 00	5.07	0 00	0.00	2 80	**27.03**	0 00	8 00	7 33	37 33	**54.00**
52	b	*E obliqua*	D	O	8.60	1 51	5 36	0 00	1 07	0 00	0.40	0 00	0.00	2 80	**19.73**	0 00	16.67	12 67	12.00	**44.67**
53	b	*E obliqua*	D	O	5.87	2 40	4 43	0 13	2.13	0 00	0 13	0.00	1 60	0.00	**16.69**	1 33	18 67	42.67	13 33	**76.67**
54	b	*E obliqua*	D	M	12.67	1 00	3 45	0 23	0 00	0 20	0 40	0 00	0 53	0 40	**18.88**	0.00	0.00	23 33	0 67	**31.33**
55	b	*E obliqua*	C	M	7 80	1.80	3 09	0 00	1 60	0 00	0 00	0 00	2 00	0.00	**16.29**	9.33	1 33	22 67	0.00	**38.67**
56	b	*E. obliqua*, *E brookeriana*	J	O	7.33	3.08	6.93	0 00	5 33	0 00	0.00	0 00	0 00	1 60	**24.28**	2 67	0 00	19 33	0 00	**74.00**
57	b	*E. obliqua*	D	O	7.27	1 76	7.01	0 20	1 60	0 00	0 00	0 00	0 00	5.73	**23.57**	0 00	16 00	20 67	14 67	**60.67**
58	b	*E obliqua*, *E brookeriana*	J	O	8 33	1.08	7 71	0.43	0 00	0 00	0 00	0 53	0 00	0.53	**18.61**	1 33	46 00	15 33	2.00	**66.67**
59	b	*E obliqua*	E	R	10 80	0 97	10 20	0.00	0 00	0 00	0 00	0.00	0 00	0 00	**21.97**	1.33	22 67	41.33	0 00	**67.33**
60	b	*E. regnans*, *E. obliqua*	E	P	22.01	0.00	2.15	0.00	1.73	1 60	0 00	0 00	0.00	0.00	**27.49**	2 67	0.00	18 67	3.33	**59.33**
61	b	*E. regnans*,	F	P	21.67	0 00	1 23	0.00	0 13	0 00	0 20	0 00	0 53	0.00	**23.76**	0.67	0 00	27.33	10.67	**80.67**

Site No	Age class	*Eucalyptus* species dominant and co-dominant	Vascular communities	Bryophyte communities	% Cover of above ground substrates										Basal area (m^2 ha^{-1})				
					Log	Fallen branch	Tree	Roots	Stump	Rock	*Dicksonia antarctica* alive/vertical	*Dicksonia antarctica* dead/horizontal	Dead tree	Upturned tree base	**Total**	Dead trees	Rainforest species	*Eucalyptus* species	*Dicksonia antarctica*	**Total**
		E obliqua																	
62	b	*E regnans*, *E. obliqua*	F	P	11.87	0 00	2 00	0.00	0 00	0 00	0 00	0.00	0.00	0 00	**13.87**	0.00	0.67	22.67	14 67	**96.00**
63	b	*E. regnans*, *E obliqua*	K	P	15.40	0 00	1 60	0 00	0 67	1 53	0 00	0 00	0 00	0 00	**19.20**	0 67	0 67	23 33	10 00	**91.33**
64	c	*E obliqua*, *E. delegatensis*	I	P	3 87	1 15	4 33	1 95	0 00	0 00	0 67	0.00	0 67	0 80	**13.43**	0 00	35.33	2 67	3 33	**41.33**
65	c	*E obliqua*, *E delegatensis*	I	N	8.53	1 67	13.55	1.40	0 00	0 00	0 00	0.00	0 00	0 00	**25.15**	0.00	28 00	10 00	4 67	**42.67**
66	b	*E regnans*, *E. delegatensis*	H	Q	8 93	0.73	4.87	0.00	3 33	0 40	0.93	0 20	0 00	0 00	**19.40**	0 00	10.00	30 67	19 33	**66.00**
67	b	*E delegatensis*	H	Q	10 53	1.63	2 33	0 28	0 00	0 00	0 27	0.00	0 00	0.00	**15.04**	0 00	0.00	42 67	13 33	**60.67**
68	b	*E delegatensis*, *E regnans*	H	Q	5.20	1.12	4 47	0 00	0.00	0.67	0.20	0 00	0 20	1 33	**13.19**	0 00	6 00	29.33	2 00	**56.00**
69	c	*E regnans*	K	P	4 93	0 84	3 91	0 00	0 00	0.00	2 53	0 00	2 40	0 00	**14.61**	1.33	10.67	10.00	20 67	**44.00**
70	c	*E regnans*	K	P	2.20	2 00	1.61	0 00	0 00	1 93	3 07	2 13	1 07	1 73	**15.75**	3 33	11 33	10.67	34 00	**60.67**
71	b	*E regnans*	F	Q	9.47	1 56	3.53	0 00	0 00	0 00	0 00	0.00	0 00	0 80	**15.36**	0 00	19 33	16 67	0 00	**90.00**
72	b	*E regnans*	F	Q	6 80	1 77	4.67	0 00	1 60	0 00	0 53	0.80	0 00	0 00	**16.17**	0 00	25 33	6 00	2 67	**63.33**
73	c	*E regnans*	K	P	11 20	2.51	3 09	0 00	1 47	4 73	1 13	0 47	0 00	0 00	**24.60**	0.00	28.67	11 33	12.67	**52.67**
74	b	*E regnans*	K	Q	5 13	1 67	5.72	0 00	0 00	1 13	0 40	0 00	0 00	0 00	**14.05**	2 67	1.33	38 00	1 33	**116.00**
75	b	*E regnans*	K	Q	7 33	2 28	5 69	0 00	7 47	1 73	0 00	0 47	0 00	0 00	**24.97**	0.00	0 67	25.33	0 00	**97.33**
76	b	*E. regnans*	G	S	5 80	0.28	3.73	0.00	0 00	10 93	0.00	0.00	2 00	5 87	**28.61**	0 00	2.00	26 67	0.00	**41.33**
77	b	*E regnans*	G	S	10.87	0 64	3 65	0 00	0 93	17.47	0.60	0 00	1 87	0 00	**36.03**	1.33	5 33	34 00	1.33	**60.67**
78	b	*E regnans*	G	S	2 87	1 16	4.12	0 00	0 00	7.80	1 87	0 80	0 13	0.00	**18.75**	0 00	1.33	40 67	16 67	**67.33**
79	c	*E regnans*	K	N	6.33	1 24	5 53	1 29	0.00	0.00	0.80	0 00	1 73	0 00	**16.93**	1.33	29.33	14.00	21 33	**67.33**
80	c	*E regnans*	K	N	9.73	1.61	3 09	1 47	0.00	0.00	1 20	0 47	0 00	0.00	**17.57**	0 67	37.33	6 00	8 67	**52.67**
81	b	*E regnans*, *E delegatensis*	A	R	24 07	0 95	1 99	0.00	3 33	0 00	0 00	0.00	1 60	0 00	**31.93**	13 33	2 67	24.00	0 00	**40.00**
82	b	*E. regnans*, *E delegatensis*	A	R	11.27	1 79	4 67	0 00	0 00	0 00	0 00	0 00	4 53	0 00	**22.25**	16 00	4.00	17 33	0.00	**37.33**
83	b	*E regnans*, *E delegatensis*	A	R	10 33	1 71	3 79	0.00	0 00	0 00	0 00	0 00	5 20	1.60	**22.63**	12 67	0 67	24 67	0 00	**38.67**
84	b	*E. regnans*	H	R	12 47	0 85	3.99	0 00	5 07	0.00	0 00	0 00	0 00	0 00	**22.37**	0 00	6 67	33 33	0.00	**41.33**
85	c	*E regnans*	K	N	13.47	1 51	8.27	2 69	2 00	0.00	1.13	0.00	0 80	0 00	**29.87**	0 00	30 00	10 00	17.33	**57.33**
86	b	*E delegatensis*, *E regnans*	H	S	12.73	0 95	8.44	0.00	4 40	6.93	0.40	0 33	0 00	5.20	**39.39**	2 67	5 33	34 00	16 67	**59.33**
87	b	*E. delegatensis*, *E regnans*	H	S	14 60	1.71	13.64	0 00	0 67	6 53	0 20	0.40	0 00	0 00	**37.75**	0 00	8 67	41 33	12 00	**67.33**
88	b	*E. regnans*	K	P	16 87	1.79	4 71	1 03	1 07	0 00	0 80	0 80	0 00	0 80	**27.85**	0 00	58.67	14 00	16.67	**89.33**

					% Cover of above ground substrates										Basal area (m^2 ha^{-1})				
Site No	Age class	*Eucalyptus* species dominant and co-dominant	Vascular communities	Bryophyte communities	Log	Fallen branch	Tree	Roots	Stump	Rock	*Dicksonia antarctica* alive/vertical	*Dicksonia antarctica* dead/horizontal	Dead tree	Upturned tree base	**Total**	Dead trees	Rainforest species	*Eucalyptus* species	*Dicksonia antarctica*	**Total**
89	b	*E regnans*	K	P	14 53	1 68	2 36	0.47	2 67	0 00	1 80	0.00	0 00	0 00	**23.51**	0.00	38 00	20.67	11 33	**70.00**
90	c	*E regnans*	K	N	7.73	1 91	3 67	0 93	1.33	0 00	0 93	0.80	1 73	0 00	**19.04**	1 33	36 67	12.00	12 67	**63.33**
91	c	*E. regnans*	K	P	10 87	1.52	8.33	0.27	0 00	0 00	1 60	0.27	3 07	0 80	**26.72**	8.67	26 00	8 00	18 67	**61.33**
92	b	*E delegatensis, E obliqua*	A	S	13.07	1.15	3 72	0 00	0.53	4 80	0 00	0 00	5.73	0 00	**29.00**	10 00	0.00	27 33	0 00	**53.33**
93	b	*E obliqua*	E	S	20 40	1.45	7.71	0.00	1 60	0 53	0 40	0.00	1 07	1 20	**34.36**	9.33	0 00	46.67	0 00	**71.33**
94	b	*E obliqua*	E	S	25 47	2.84	6 28	0 00	0 00	5.60	0 00	0 60	2.67	0 00	**43.45**	3.33	0.00	39 33	0 67	**65.33**
95	b	*E obliqua*	E	S	19 33	2 97	5 20	0 00	1 20	16.60	0 00	0.00	5 33	0 00	**50.64**	0.00	0.00	40 00	0 00	**65.33**
96	b	*E. regnans*	K	P	5 53	0 77	1.93	0.20	0 00	0 00	2 53	5.93	0 00	4 40	**21.31**	0.00	37 33	6 00	23 33	**79.33**
97	b	*E regnans*	J	N	9.93	0 72	2 93	3.65	0 00	0.00	0 67	3 40	0 00	0 00	**21.31**	0 00	40.67	3 33	22.67	**67.33**
98	b	E obliqua	C	R	6.73	2 15	9 24	0.00	0.00	0 00	0 00	0.00	7 87	0 00	**25.99**	7 33	6 00	59 33	0 00	**108.00**
99	b	E obliqua	E	R	8 07	2 49	9 33	0 00	0 00	0 00	0 00	0 00	0.47	0 00	**20.36**	0 00	34.00	36 67	4 00	**77.33**
100	a	E regnans, E delegatensis	H	V	15 73	1.31	3 16	0 00	6.53	4 40	0 00	1 87	0 00	0 00	**33.00**	0 00	0 67	6.67	0 00	**32.67**
101	a	E regnans, E delegatensis	H	V	13 80	0 76	3 32	0 00	0 00	8 20	0 00	0 00	0 00	0 00	**26.08**	0 00	0 00	33.32	0 00	**35.32**
102	a	E regnans, E delegatensis	H	V	13.40	1 04	0.51	0.00	4 93	1 80	0 00	0.53	0 00	1 60	**23.81**	2 00	0 00	3 33	0 00	**20.67**
103	a	E regnans, E delegatensis	H	V	16 87	1.52	0 72	0 00	10 27	0 00	0.67	1 27	0 00	0 00	**31.31**	5.33	0.00	0 67	1 33	**10.00**
104	a	E regnans	H	T	32.07	0.73	0.65	0 00	8.13	0.00	0 00	0 80	0 00	0 00	**42.39**	1.33	0.00	0.00	0 00	**12.00**
105	a	E. regnans -	H	T	17.80	0.27	0 85	0 00	6.93	0 00	0.47	1 47	0 00	0 00	**27.79**	0 00	0 00	12 67	2 00	**14.67**

Appendix 8.3. Vascular plant species in 105 sites listed according to lifeform. Rainforest status is: 1 = rainforest species, 2 = dubious rainforest species, 3 = non-rainforest species after (Jarman et al *1991).* [e] *indicates endemic species,* [i] *indicates invasive species after Buchanan (1999).*

Species	Family	Rainforest status
Trees		
Acacia dealbata	Mimosaceae	2
Acacia melanoxylon	Mimosaceae	2
Acacia mucronata	Mimosaceae	2
Acacia riceana [e]	Mimosaceae	2
Acacia verticillata	Mimosaceae	3
Atherosperma moschatum	Monimiaceae	1
Eucalyptus brookeriana	Myrtaceae	3
Eucalyptus delegatensis ssp. *tasmaniensis* [e]	Myrtaceae	3
Eucalyptus obliqua	Myrtaceae	3
Eucalyptus regnans	Myrtaceae	3
Eucalytpus nitida	Myrtaceae	3
Eucryphia lucida [e]	Eucryphiaceae	1
Leptospermum lanigerum	Myrtaceae	2
Leptospermum scoparium	Myrtaceae	2
Leptospermum spp.	Myrtaceae	2
Melaleuca squarrosa	Myrtaceae	2
Nothofagus cunninghamii	Fagaceae	1
Phyllocladus asplenifolius [e]	Phyllocladaceae	1
Tall shrubs		
Anodopetalum biglandulosum [e]	Cunoniaceae	1
Anopterus glandulosus [e]	Escalloniaceae	1
Banksia marginata	Proteaceae	3
Cassinia acueleata	Asteraceae	3
Cenarrhenes nitida [e]	Proteaceae	1
Hakea lissosperma	Proteaceae	3
Monotoca glauca	Epacridaceae	1
Monotoca linifolia	Epacridaceae	3
Notelaea ligustrina	Oleaceae	1
Olearia argophylla	Asteraceae	1
Nematolepis squamea ssp. *squamea*	Rutaceae	2
Pittosporum bicolor	Pittosporaceae	1
Pomaderris apetala	Rhamnaceae	2
Prostanthera lasianthos	Lamiaceae	2
Tasmannia lanceolata	Winteraceae	1
Short shrubs		
Bauera rubioides	Cunoniaceae	2
Bossiaea cinerea	Fabaceae	3
Coprosma quadrifida	Rubiaceae	1
Correa lawrenciana	Rutaceae	2
Cyathodes glauca [e]	Epacridaceae	2
Cyathodes juniperina	Epacridaceae	1
Cyathodes parvifolia [e]	Epacridaceae	1
Epacridaceae spp.	Epacridaceae	1
Gaultheria hispida	Ericaceae	1
Gonocarpus humilis	Haloragaceae	3
Gonocarpus teucroides	Haloragaceae	3
Olearia persoonioides [e]	Asteraceae	1
Orites diversifolia [e]	Proteaceae	1
Oxylobium ellipticum	Fabaceae	3
Ozothamnus thyrsoides	Asteraceae	3
Pimelea cinerea [e]	Thymelaeaceae	1
Pimelea drupacea	Thymelaeaceae	1
Pimelea linifolia	Thymelaeaceae	1

Species	Family	Rainforest status
Pultenaea daphnoides	Fabaceae	3
Telopea truncata [e]	Proteaceae	1
Trochocarpa cunninghamii	Epacridaceae	1
Trochocarpa disticha [e]	Epacridaceae	1
Trochocarpa gunnii [e]	Epacridaceae	1
Non-woody angiosperms		
Acaena novae-zelandiae	Rosaceae	3
Agrostis spp.	Poaceae	3
Carex appressa	Cyperaceae	1
Carex spp.	Cyperaceae	1
Chiloglottis pedunculata	Orchidaceae	3
Chiloglottis spp	Orchidaceae	3
Corybas spp.	Orchidaceae	2
Dianella tasmanica	Liliaceae	1
Drymophila cyanacarpa	Liliaceae	1
Euchiton spp.	Asteraceae	3
Gahnia grandis	Cyperaceae	1
Gahnia spp.	Cyperaceae	1
Hydrocotyle hirta	Apiaceae	1
Hydrocotyle spp. a	Apiaceae	1
Hydrocotyle spp. b	Apiaceae	1
Juncus bufonius	Juncaceae	3
Juncus sarophorus	Juncaceae	3
Juncus spp.	Juncaceae	3
Lepidosperma elatius	Cyperaceae	2
Oxalis spp.	Oxalidaceae	3
Poa spp.	Poaceae	3
Pratia spp.	Campanulaceae	3
Pterostylis spp.	Orchidaceae	3
Rubus parvifolius	Rosaceae	3
Senecio spp.	Asteraceae	3
Stellaria pungens	Caryophyllaceae	3
Uncinia spp.	Cyperaceae	1
Uncinia tenella	Cyperaceae	1
Urtica incisa	Urticaceae	1
Viola hederacea	Violaceae	1
Wahlenbergia spp.	Campanulaceae	3
Ground ferns		
Blechnum nudum	Blechnaceae	1
Blechnum penna-marina	Blechnaceae	1
Blechnum wattsii	Blechnaceae	1
Calochlaena dubia	Culcitaceae	2
Cyathea australis	Cyatheaceae	1
Dicksonia antarctica	Dicksoniaceae	1
Histiopteris incisa	Dennstaedtiaceae	1
Huperzia varia	Lycopodiaceae	2
Hypolepis rugosula	Dennstaedtiaceae	1
Polystichum proliferum	Dryopteridaceae	1
Pteridium esculentum	Dennstaedtiaceae	2
Sticherus spp.	Gleicheniaceae	1
Sticherus tener	Gleicheniaceae	1
Epiphytic ferns		
Asplenium bulbiferum	Aspleniaceae	1
Asplenium flabellifolium	Aspleniaceae	1
Asplenium flaccidum	Aspleniaceae	1
Asplenium spp.	Aspleniaceae	1
Ctenopteris heterophylla	Grammitidaceae	1
Cystopteris tasmanica	Athyriaceae	1
Grammitis billardieri	Grammitidaceae	1

Species	Family	Rainforest status
Grammitis magellanica ssp. *nothofageti*	Grammitidaceae	1
Grammits pseudociliatus	Grammitidaceae	1
Grammitis sp. a	Grammitidaceae	1
Grammitis sp. b	Grammitidaceae	1
Hymenophyllum australe	Hymenophyllaceae	1
Hymenophyllum cupressiforme	Hymenophyllaceae	1
Hymenophyllum flabellatum	Hymenophyllaceae	1
Hymenophyllum marginatum	Hymenophyllaceae	1
Hymenophyllum peltatum	Hymenophyllaceae	1
Hymenophyllum rarum	Hymenophyllaceae	1
Hymenophyllum spp.	Hymenophyllaceae	1
Microsorum pustulatum	Polypodiaceae	1
Crepidomanes venosum	Hymenophyllaceae	1
Rumohra adiantiformis	Dryopteridaceae	1
Tmesipteris obliqua	Psilotaceae	1
Tmesipteris spp.	Psilotaceae	1
Climbers		
Billardiera longifolia	Pittosporaceae	3
Billardiera scandens	Pittosporaceae	3
Clematis aristata	Ranunculaceae	1
Prionotes cerinthoides [e]	Epacridaceae	1
Rubus fruticosus [i]	Rosaceae	3

Appendix 8.4. Bryophyte species recorded from 105 sites listed according to lifeform.

Species	Family
Acrocarpous moss	
Atrichum androgynum	Polytrichaceae
Barbula calycina	Pottiaceae
Bryum crassum	Bryaceae
Bryum pseudotriquetrum	Bryaceae
Calyptopogon mnioides	Pottiaceae
Campylopus bicolor var *ericeticola*	Dicranaceae
Campylopus clavatus	Dicranaceae
Campylopus flindersii	Dicranaceae
Campylopus introflexus	Dicranaceae
Campylopus purpureocaulis Dusén	Dicranaceae
Campylopus pyriformis	Dicranaceae
Campylopus pyriformis var. a	Dicranaceae
Ceratodon purpureus	Ditrichaceae
Dawsonia superba Grev. var. *pulchra* Zant.	Dawsoniaceae
Dicranoloma billardieri	Dicranaceae
Dicranoloma dicarpum	Dicranaceae
Dicranoloma menziesii	Dicranaceae
Dicranoloma platycaulon	Dicranaceae
Dicranoloma robustum	Dicranaceae
Dicranoloma robustum var. *setosum*	Dicranaceae
Ditrichum cylindricarpum	Ditrichaceae
Ditrichum difficile	Ditrichaceae
Fissidens pallidus	Fissidentaceae
Fissidens pungens	Fissidentaceae
Fissidens taylorii	Fissidentaceae
Fissidens tenellus	Fissidentaceae
Funaria hygrometrica	Funariaceae
Goniobryum subbasilare	Rhizogonaceae
Grimmia trichophylla	Grimmiaceae
Holomitrium perichaetiale	Dicranaceae
Hypnodendron comosum	Hypnodendraceae
Hypnodendron spininervium ssp. *archeri*	Hypnodendraceae
Hypnodendron spp.	Hypnodendraceae
Hypnodendron vitiense ssp. *australe*	Hypnodendraceae
Leptostomum inclinans	Bryaceae
Leptotheca gaudichaudii	Aulacomniaceae
Leucobryum candidum	Leucobryaceae
Macrocoma tenue ssp. *tenue*	Orthotrichaceae
Macromitrium archeri	Orthotrichaceae
Macromitrium ligulaefolium	Orthotrichaceae
Macromitrium microstomum	Orthotrichaceae
Mittenia plumula	Mitteniaceae
Orthodontium lineare	Bryaceae
Orthodontium sp. a	Bryaceae
Orthotrichum tasmanicum var. *tasmanicum*	Orthotrichaceae
Pogonatum subulatum	Polytrichaceae
Pohlia nutans	Bryaceae
Pohlia sp. a	Bryaceae
Polytrichum juniperinum	Polytrichaceae
Ptychomitrium australe	Ptychomitriaceae
Racomitrium crispulum var. *tasmanicum*	Grimmiaceae

Species	Family
Rhizogonium distichum	Rhizogonaceae
Rhizogonium novaehollandiae	Rhizogonaceae
Rhizogonium pennatum var. *aristatum*	Rhizogonaceae
Rosulabryum billardieri var. *billardieri* (Schwägr.) Spence	Bryaceae
Rosulabryum campylothecium (Tayl.) Spence	Bryaceae
Rosulabryum capillare (Hedw.) Spence	Bryaceae
Ulota lutea	Orthotrichaceae
Ulota sp. a	Orthotrichaceae
Ulota viridis	Orthotrichaceae
Zygodon intermedius	Orthotrichaceae
Pleurocarpous moss	
Achrophyllum dentatum	Hookeriaceae
Acrocladium chlamydophyllum	Amblystegiaceae
Brachythecium paradoxum	Brachytheciaceae
Calyptrochaeta apiculata	Hookeriaceae
Calyptrochaeta brownii (Dix.) J.K.Bartlett	Hookeriaceae
Camptochaete arbuscula	Lembophyllaceae
Camptochaete deflexa (Wilson) Jaeg.	Lembophyllaceae
Catagonium nitens (Brid.) Cardot ssp. *nitens*	Phyllogoniaceae
Brachythecium salebrosum (F. Weber & D. Mohr) Schimp.	Brachytheciaceae
Brachythecium salebrosum/ rutabulum	Brachytheciaceae
Cyathophorum bulbosum	Hypopterygiaceae
Daltonia splachnoides	Hookeriaceae
Distichophyllum crispulum	Hookeriaceae
Distichophyllum microcarpum	Hookeriaceae
Distichophyllum pulchellum	Hookeriaceae
Distichophyllum rotundifolium	Hookeriaceae
Glyphothecium sciuroides	Ptychomniaceae
Hampeella alaris	Ptychomniaceae
Hypnum chrysogaster	Hypnaceae
Hypnum cupressiforme	Hypnaceae
Hypopterygium didictyon Müll.Hal.	Hypopterygiaceae
Isopterygium limatum	Hypnaceae
Lembophyllum divulsum	Lembophyllaceae
Lopidium concinnum	Hypopterygiaceae
Neckera pennata	Neckeraceae
Papillaria flavolimbata	Meteoriaceae
Plagiothecium lamprostachys (Hampe.) Jaeg.	Plagiotheciaceae
Ptychomnion aciculare	Ptychomniaceae
Pyrrhobryum mnioides	Rhizogonaceae
Pyrrhobryum parramattense	Rhizogonaceae
Racopilum cuspidigerum (Schwägr.) Ångstr. var. *convolutaceum* (Müll.Hal.) Zant. & Dijk.	Racopilaceae
Rhaphidorrhynchium amoenum	Sematophyllaceae
Rhynchostegium tenuifolium	Brachytheciaceae
Sauloma tenella	Hookeriaceae
Sematophyllum subhumile var. *contiguum* (Mitt.) Tan, Schofield & Ramsay	Sematophyllaceae
Sematophyllum uncinatum	Sematophyllaceae
Sphagnum australe	Sphagnaceae
Sphagnum falcatulum	Sphagnaceae
Thamnobryum pumilum	Neckeraceae
Thuidium furfurosum	Thuidiaceae
Thuidium sparsum	Thuidiaceae

Species	Family
Trachyloma planifolium	Pterobryaceae
Warburgiella leucocytus (Müll.Hal.) Tan, Schofield & Ramsay	Sematophyllaceae
Weymouthia cochlearifolia	Lembophyllaceae
Weymouthia mollis	Lembophyllaceae
Wijkia extenuata	Sematophyllaceae
Leafy Liverwort	
Acrobolbus cinerascens	Acrobolbaceae
Acrobolbus concinnus	Acrobolbaceae
Acrochila biserialis	Plagiochilaceae
Acromastigum colensoanum	Lepidoziaceae
Acromastigum mooreanum	Lepidoziaceae
Adelanthus bisetulus	Adelanthaceae
Adelanthus falcatus	Adelanthaceae
Anastrophyllum schismoides	Jungermanniaceae
Balantiopsis diplophylla	Balantiopsaceae
Bazzania involuta	Lepidoziaceae
Bazzania monilinervis	Lepidoziaceae
Brevianthus flavus	Brevianthaceae
Cephaloziella exiliflora	Cephaloziellaceae
Cephaloziella hirta	Cephaloziellaceae
Chandonanthus squarrosus	Jungermanniaceae
Cheilolejeunea albo-virens	Lejeuneaceae
Cheilolejeunea campbelliensis	Lejeuneaceae
Cheilolejeunea mimosa	Lejeuneaceae
Chiloscyphus bispinosus	Geocalycaceae
Chiloscyphus bispinosus aff.	Geocalycaceae
Chiloscyphus echinellus	Geocalycaceae
Chiloscyphus latifolius (L.) Engel & Schust.	Geocalycaceae
Chiloscyphus leucophyllus	Geocalycaceae
Chiloscyphus minor (Nees) Engel & Schust.	Geocalycaceae
Chiloscyphus multipennus aff.	Geocalycaceae
Chiloscyphus muricatus	Geocalycaceae
Chiloscyphus novaezeelandiae	Geocalycaceae
Chiloscyphus pallidus	Geocalycaceae
Chiloscyphus rupicolus (Steph.) Engel & Schust.	Geocalycaceae
Chiloscyphus semiteres	Geocalycaceae
Chiloscyphus subporosus	Geocalycaceae
Chiloscyphus villosus	Geocalycaceae
Cryptochila grandiflora	Jungermanniaceae
Cuspidatula monodon	Jungermanniaceae
Diplasiolejeunea plicatiloba	Lejeuneaceae
Drepanolejeunea aucklandica	Lejeuneaceae
Frullania aterrima	Frullaniaceae
Frullania clavata	Frullaniaceae
Frullania falciloba	Frullaniaceae
Frullania monocera	Frullaniaceae
Frullania pentapleura	Frullaniaceae
Frullania probosciphora	Frullaniaceae
Frullania rostrata	Frullaniaceae
Gackstroemia weindorferi	Lepidolaenaceae
Geocalyx caledonicus	Geocalycaceae
Heteroscyphus argutus	Geocalycaceae
Heteroscyphus biciliatus (Hook.f. & Tayl.) Engel	Geocalycaceae

Species	Family
Heteroscyphus billardieri	Geocalycaceae
Heteroscyphus coalitus	Geocalycaceae
Heteroscyphus conjugatus	Geocalycaceae
Heteroscyphus decipiens	Geocalycaceae
Heteroscyphus fissistipus	Geocalycaceae
Heteroscyphus knightii	Geocalycaceae
Heteroscyphus limosus	Geocalycaceae
Heteroscyphus sinuosus	Geocalycaceae
Heteroscyphus sp. a.	Geocalycaceae
Heteroscyphus triacanthus	Geocalycaceae
Isotachis intortifolia	Balantiopsaceae
Jamesoniella tasmanica	Jungermanniaceae
Jungermannia inundata	Jungermanniaceae
Kurzia compacta (Steph.) Grolle	Lepidoziaceae
Kurzia hippurioides	Lepidoziaceae
Kurzia sexfida	Lepidoziaceae
Kurzia tenax	Lepidoziaceae
Lejeunea drummondii	Lejeuneaceae
Lejeunea primordialis	Lejeuneaceae
Lejeunea spp.	Lejeuneaceae
Lepicolea scolopendra	Lepicoleaceae
Lepidozia concinna	Lepidoziaceae
Lepidozia glaucophylla	Lepidoziaceae
Lepidozia laevifolia	Lepidoziaceae
Lepidozia obtusiloba Steph.	Lepidoziaceae
Lepidozia pendulina	Lepidoziaceae
Lepidozia procera	Lepidoziaceae
Lepidozia ulothrix	Lepidoziaceae
Leptophyllopsis laxus	Geocalycaceae
Marsupidium setulosum	Acrobolbaceae
Marsupidium surculosum	Acrobolbaceae
Paraschistochila pinnatifolia	Schistochilaceae
Paraschistochila tuloides	Schistochilaceae
Plagiochila baileyana	Plagiochilaceae
Plagiochila circinalis	Plagiochilaceae
Plagiochila fasciculata	Plagiochilaceae
Plagiochila fuscella	Plagiochilaceae
Plagiochila incurvicolla	Plagiochilaceae
Plagiochila radiculosa	Plagiochilaceae
Plagiochila retrospectans	Plagiochilaceae
Plagiochila spp.	Plagiochilaceae
Plagiochila strombifolia	Plagiochilaceae
Psiloclada clandestina	Lepidoziaceae
Radula buccinifera	Radulaceae
Radula compacta	Radulaceae
Radula multiamentula	Radulaceae
Radula ratkowskiana	Radulaceae
Radula retroflexa	Radulaceae
Radula spp.	Radulaceae
Radula tasmanica	Radulaceae
Saccogynidium decurvum	Geocalycaceae
Schistochila lehmanniana	Schistochilaceae
Schistochila pseudociliata	Schistochilaceae

Species	Family
Schistochila tasmanica	Schistochilaceae
Telaranea centipes	Lepidoziaceae
Telaranea mooreana	Lepidoziaceae
Telaranea patentissima	Lepidoziaceae
Telaranea tetradactyla	Lepidoziaceae
Kurzia hippurioides aff.	Lepidoziaceae
Teleranea herzogii (Hodgs.) Hodgs.	Lepidoziaceae
Temnoma townrowii	Blepharostomataceae
Trichocolea mollissima	Tricholeaceae
Tylimanthus diversifolius Hodgs.	Acrobolbaceae
Tylimanthus pseudosaccatus	Acrobolbaceae
Tylimanthus tenellus	Acrobolbaceae
Zoopsis argentea	Lepidoziaceae
Zoopsis leitgebiana	Lepidoziaceae
Zoopsis setulosa	Lepidoziaceae
Thallose Liverwort	
Aneura alterniloba	Aneuraceae
Hymenophyton flabellatum	Metzgeriaceae
Marchantia berteroana	Marchantiaceae
Metzgeria decipiens	Metzgeriaceae
Metzgeria saccata	Metzgeriaceae
Metzgeria spp.	Metzgeriaceae
Pallavicinia lyellii (Hook.) Gray	Pallavicinaceae
Pallaviciniaceae	Pallaviciniaceae
Podomitrium phyllanthus	Pallavicinaceae
Riccardia aequicellularis	Aneuraceae
Riccardia cochleata	Aneuraceae
Riccardia colensoi	Aneuraceae
Riccardia crassa	Aneuraceae
Riccardia eriocaula	Aneuraceae
Riccardia spp.	Aneuraceae
Riccardia wattsiana	Aneuraceae
Symphyogyna podophylla	Pallavicinaceae
Treubia tasmanica	Treubiaceae

Appendix 8.5. Number of vascular plant and bryophyte species taxa per lifeform for all age classes. Number of sites = n.

Lifeform	Number of species	Average species richness n = 105 (± SE)	Number of genera	Number of families
Vascular plants				
Total	128	16.71 ± 0.44	82	49
Trees	18	3.9±0.13	8	6
Tall shrubs	15	2.51 ±0.14	14	11
Short shrubs	23	1.24±0.15	16	10
Non-woody angiosperms	31	1.53±0.17	23	13
Ferns	36	7.39±0.38	19	14
Ground ferns	14	3.26±0.15	11	8
Epiphytic ferns	22	4.13±0.32	8	6
Climbers	5	0.13±0.03	4	4
Bryophytes				
Total	240	51.90±1.93	116	54
Mosses	107	24.82±0.88	67	32
Liverworts	133	27.09±1.29	49	22

Appendix 8.6. Description and two way sorted table of vascular plant species with > 20% frequency in at least one vascular plant community. Lf = lifeform: T = tree. S = tall shrub, H = short shrub, N = non-woody angiosperm, GF = ground fern, EF = epiphytic fern, C = climber. Rf = rainforest status: 1 = rainforest species, 2 =dubious rainforest species, 3 =non-rainforest species after (Jarman et al *1991). Communities labelled A to K* (see Appendix 8.2 for more details).

Community A consists of old growth and late regrowth forest in the southern district. It is best characterised by *Trochocarpa disticha* and *Anopterus glandulosus* and has *Phyllocladus asplenifolius* as its most constant species. Community B consists early regrowth forest from the northern and southern districts. *Acacia verticillata, Leptospermum scoparium* and *Melaleuca squarrosa* characterise this community with many short shrubs and non-woody angiosperms frequent in the understorey. Community C consists of early and late regrowth forest sites of the southern and northern districts. *Eucalyptus obliqua, Gahnia grandis, Monotoca glauca* and *Blechnum wattsii* are the most common species. Late regrowth sites from the northern district make up Community D. Ferns (*Pteridium esculentum, Polystichum proliferum, Histiopteris incisa, Hymenophyllum cupressiforme)* best differentiate this community with *E. obliqua* dominant. Community E also consists of late regrowth sites but from the southern district. It is distinguished by *Cyathodes glauca* and *Coprosma quadrifida* and has *E. obliqua, Dicksonia antarctica,* and *Pomaderris apetala* as its most common species. Community F is late regrowth from the southern and central districts. *Olearia argophylla* and *Pomaderris apetala* characterise this community with *Eucalyptus regnans* and *Acacia dealbata* common in the overstorey. Community G is late regrowth forest from the southern district, also with by *E. regnans* and *A. dealbata* common in the overstorey. *Acacia melanoxylon, Dianella tasmanica, Nematolepis squamea* and *Clematis aristata* are highly constant understorey species. Community H is early and late regrowth forest of the central district. It is differentiated by *Eucalyptus delegatensis* with *E. regnans, Dicksonia antarctica, Nothofagus cunninghamii, Cassinia aculeata, Senecio* spp. and *Acaena novae-zelandiae* as constant species. Community I is old growth forest from all districts. It has a rainforest understorey characterised by *Eucryphia lucida, Anodopetalum biglandulosum, Atherosperma moschatum* and *Nothofagus cunninghamii. Blechnum wattsii* and *E. obliqua* are also common. Community J consists of old growth and late regrowth sites mostly from the northern district with some sites from the southern district. Like Community I, it has a rainforest understorey with *E. obliqua* in the overstorey, but it is characterised by an understorey rich in epiphytic ferns such as *Microsorum pustulatum, Hymenophyllum rarum, H australe* and *Crepidomanes venosum.* Community K largely consists of central district sites. It has tree strata in which *N. cunninghamii, Atherosperma moschatum* and *E. regnans* are common. It is characterised ferns such as *Dicksonia antarctica, Hymenophyllum flabellatum, Grammitis billardierei* and *H. peltatum.*

Appendix 8.6 continued. Two way sorted table of vascular plant species with > 20% frequency in at least one vascular plant community.

Species/Community	Lf	Rf	A	B	C	D	E	F	G	H	I	J	K
Phyllocladus asplenifolius	T	1	100.0		66.7	50.0	44.4			16.7	62.5	20.0	18.8
Anopterus glandulosus	S	1	90.9		16.7				33.3		25.0		12.5
Cenarrhenes nitida	S	1	54.6		50.0	25.0					50.0		12.5
Tasmannia lanceolata	S	1	54.6			50.0	44.4			16.7		5.0	6.3
Acacia riceana	T	2	36.4	25.0	16.7		11.1						
Hymenophyllum marginatum	EF		27.3				11.1						
Orites diversifolia	H	1	27.3									5.0	
Trochocarpa disticha	H	1	72.7										
Acacia verticillata	T	3		100.0		16.7	33.3						
Gonocarpus teucroides	H	3		50.0									
Epacridaceae spp.	H	1		50.0	33.3	8.3							
Leptospermum scoparium	T	2	9.1	50.0	16.7						12.5		
Melaleuca squarrosa	T	2	9.1	50.0	16.7	16.7							
Juncus bufonius	N	3		25.0									
Gonocarpus humilis	H	3		25.0									
Pultenaea daphnoides	H	3		25.0									
Pimelea linifolia	H	1		25.0									
Correa lawrenciana	H	2	9.1	25.0									
Acacia mucronata	T	2	9.1	25.0	16.7								
Olearia persoonioides	H	1	18.2	25.0			22.2						
Notelaea ligustrina	S	1		25.0			11.1			8.3		10.0	6.3
Lepidosperma elatius	N	2		25.0								5.0	
Pimelea cinerea	H	1	18.2	25.0								5.0	
Carex appressa	N	1	9.1	25.0								5.0	
Poa spp.	N	3		25.0		16.7				8.3		20.0	6.3
Pimelea drupacea	H	1	9.1	25.0	16.7	8.3	11.1					5.0	6.3
Gahnia grandis	N	1	63.6	100.0	100.0	83.3	66.7	25.0		66.7	25.0	50.0	12.5
Eucalyptus obliqua	T	3	45.5	100.0	100.0	100.0	100.0				87.5	90.0	
Monotoca glauca	S	1	63.6	50.0	100.0	50.0	66.7		100.0	33.3	25.0	15.0	
Blechnum wattsii	GF	1	90.9	25.0	100.0	8.3	55.6			25.0	100.0	45.0	62.5
Drymophila cyanocarpa	N	1	18.2		33.3					8.3			
Pteridium esculentum	GF	2	54.6	50.0	66.7	100.0	66.7	25.0	66.7	50.0		35.0	37.5
Polystichum proliferum	GF	1	45.5		16.7	100.0	33.3	75.0	66.7	41.7	37.5	90.0	62.5
Histiopteris incisa	GF	1	54 6	25.0	50.0	91.7	55.6		33.3	75.0	12.5	65.0	75.0
Hymenophyllum cupressiforme	EF	1	18.2		16.7	66.7	22.2	50.0			12.5	65.0	12.5
Grammitis sp. a	EF	1	18.2			66.7	55.6	25.0	66 7	8.3	50.0	65.0	56.3
Cyathodes juniperina	H	1	45.5		33.3	50.0				8.3	12.5	5.0	
Blechnum nudum	GF	1				33.3	11.1			16.7		20.0	6.3
Rumohra adiantiformis	EF	1				33.3		25.0	33.3		12.5	20.0	12.5
Hydrocotyle hirta	N	1				33.3				8.3		10.0	
Billardiera longifolia	C	3				25.0							
Coprosma quadrifida	H	1	18.2			33.3	55.6			41.7	25.0	45.0	31.3
Cyathodes glauca	H	2	72.7		33.3		88.9			16.7	12.5		
Olearia argophylla	S	1				8.3	22.2	100.0	66.7	75.0		45.0	50.0
Pomaderris apetala	S	2	9.1	75.0		50.0	88.9	100.0		33.3		35.0	43.8

Species/Community	Lf	Rf	A	B	C	D	E	F	G	H	I	J	K
Asplenum bulbiferum	EF	1						75.0		8.3	75.0	30.0	31.3
Tmesipteris spp.	EF	1				16.7	11.1	50.0				35.0	12.5
Acacia dealbata	T	2	9 1	50.0	33.3		44.4	100.0	100.0	83.3			12.5
Eucalyptus regnans	T	3	27.3				11.1	100.0	100.0	91.7	12.5	5.0	93.8
Oxylobium ellipticum	H	3		25.0					33.3				
Monotoca linifolia	S	3							33.3				
Hydrocotyle sp. a	N	1				8.3			33.3	25.0			
Trochocarpa cunninghamii	H	1	27.3		16.7	8.3			33.3	8.3		5.0	
Nematolepis squamea ssp. *squamea*	S	2	54.6	75.0	66.7	75.0	77.8		100.0	16.7	12.5	20.0	31.3
Dianella tasmanica	N	1			50.0	16.7	11.1		100.0		12.5	5.0	
Acacia melanoxylon	T	2	9.1		33.3	58.3			100.0	41.7	12.5	25 0	
Clematis aristata	C					8.3			66.7	25.0			6.3
Urtica incisa	N	1		25.0		8.3			33.3				
Hydrocotyle sp. b	N	1							66.7	16.7			12.5
Chiloglottis spp.	N	3				16.7			33.3	8.3			18.8
Cystopteris tasmanica	EF	1							33.3				
Agrostis rudis	N	3							33.3				
Chiloglottis pedunculata	N	3							33.3			5.0	
Eucalyptus delegatensis ssp. *tasmaniensis*	T	3	63.6				22.2			66.7			
Senecio spp.	N	3	9.1	50.0		16.7			33.3	58.3		5.0	
Cassinia aculeata	S	3	9.1			8.3				41.7			
Acaena novae-zelandiae	N	3	9.1			16.7				41.7			6.3
Gaultheria hispida	H	1	18.2							25.0			
Eucryphia lucida	T	1	54.6	25.0	66.7	58.3	33.3				100.0	35.0	6.3
Anodopetalum biglandulosum	S	1	27.3	25.0	50.0	8.3				25.0	87.5		
Atherosperma moschatum	T	1	36.4			50.0	33.3	25.0		8.3	87.5	55.0	81.3
Grammitis sp. b	EF	1	9.1								50.0		6.3
Grammitis magellanica ssp. *nothofageti*	EF	1	9.1				22.2			8.3	37.5	25.0	6.3
Hymenophyllum spp.	EF	1	9.1			8.3	11.1			8.3	25.0	20.0	6.3
Nothofagus cunninghamii	T	1	72.7		50.0	91.7	44.4			83.3	100.0	100.0	81.3
Microsorum pustulatum	EF	1			16.7	41.7		75.0	66.7		75.0	95.0	18.8
Hymenophyllum rarum	EF	1	18.2		16.7	66.7	11.1		33.3		62.5	85.0	37.5
Hymenophyllum australe	EF	1	9.1		16.7	16.7					50.0	60.0	37.5
Crepidomanes venosum	EF	1									25.0	60.0	18.8
Pittosporum bicolor	S	1	9.1		16.7	25.0	11.1			8.3	25.0	30.0	6.3
Tmesipteris oblqua	EF	1					22.2				25.0	30.0	18.8
Ctenopteris heterophylla	EF	1					11.1				25.0	35.0	25.0
Asplenium spp.	EF	1										20.0	
Dicksonia antarctica	GF	1	45.5			66.7	100.0	75.0	66.7	91.7	62.5	95.0	100.0
Hymenophyllum flabellatum	EF	1			33.3	25.0	22.2	50.0			75.0	75.0	87.5
Grammitis billardierei	EF	1	36.4		33.3	25.0	11.1	25.0	66.7		50.0	80.0	81.3
Hymenophyllum peltatum	EF	1	54.6			25.0	66.7	25.0	66.7	8.3		40.0	68.8

*Appendix 8.7. Species – substrate/age class associations. Significance values from chi-square test. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, ns = not significant, '-' before the digit signifies a negative relationship, dash alone indicates cells with expected counts less than 5 or 0. Number of sites (n) in age class: age class a, 1 - 18 years, n = 18;age class b 31 - 67 years, n = 54; age class c, > 110 years, n = 33. Total occurrence of species is the total of observations from 1118 samples. Abbreviations: a, b and c are age class a, b or c respectively; T = tree, S = tall shrub, H = short shrub.*

Species	Total occurrence of species	*Acacia dealbata* T (b)	*Acacia melanoxylon* T (b)	*Atherosperma moschatum* T (c)	*Eucalyptus delegatensis* T (b)	*Eucalyptus obliqua* T (b)	*Eucalyptus obliqua* T (c)	*Eucalyptus regnans* T (b)	*Eucalyptus regnans* T (c)	*Eucryphia lucida* T (b)	*Eucryphia lucida* T (c)	*Nothofagus cunninghamii* T (b)
Achrophyllum dentatum	214	-	-	-	-	-0.0390	-	-	-	-	-	-
Balantiopsis diplophylla	107	-	-	-	-	-	-	-	-	-	-	-
Bazzania involuta	631	-0.0000	-0.0000	-0.0210	-0 0195	+0.0005	+0.0000	ns	+0.0315	ns	ns	ns
Bazzania monilinervis	115	-	-	-	-	-	-	-	-	-	-	-
Chiloscyphus echinellus	224	-	-	-	-	-0 0084	-	-	-	-	-	-
Dicranoloma menziesii	445	-0.0002	ns	+0.0000	-	-0.0000	-0.0080	-0.0001	-	-	-	ns
Dicranoloma robustum	144	-	-	-	-	-	-	-	-	-	-	-
Dicranoloma robustum var. *setosum*	194	-	-	-	-	-	-	-	-	-	-	-
Gackstroemia weindorferi	217	-	-	-	-	-0.0367	-	-	-	-	-	-
Heteroscyphus coalitus	391	ns	ns	-0.0002	-	-0.0261	-0 0075	-0.0135	-	-	-	ns
Heteroscyphus fissistipus	372	ns	ns	-0 0087	-	ns	-0 0006	-0 0197	-	-	-	ns
Hymenophyton flabellatum	111	-	-	-	-	-	-	-	-	-	-	-
Hypnum chrysogaster	297	ns	-0.0275	ns	-	-0 0225	ns	-0.0223	-	-	-	ns
Kurzia hippurioides	142	-	-	-	-	-	-	-	-	-	-	-
Lepidozia laevifolia	154	-	-	-	-	-	-	-	-	-	-	-
Lepidozia procera	164	-	-	-	-	-	-	-	-	-	-	-
Lepidozia ulothrix	544	-0.0000	-0 0000	-0.0058	-	ns	ns	ns	-	-	-	ns
Leucobryum candidum	191	-	-	-	-	-	-	-	-	-	-	-
Lopidium concinnum	120	-	-	-	-	-	-	-	-	-	-	-
Metzgeria decipiens	213	-	-	-	-	ns	-	-	-	-	-	-
Plagiochila fasciculata	105	-	-	-	-	-	-	-	-	-	-	-
Ptychomnion aciculare	493	ns	ns	ns	-	-0.0001	-0.0001	-0.0012	-	-	-	-0.0036
Radula buccinifera	144	-	-	-	-	-	-	-	-	-	-	-

Species	Total occurrence of species	*Acacia dealbata* T (b)	*Acacia melanoxylon* T (b)	*Atherosperma moschatum* T (c)	*Eucalyptus delegatensis* T (b)	*Eucalyptus obliqua* T (b)	*Eucalyptus obliqua* T (c)	*Eucalyptus regnans* T (b)	*Eucalyptus regnans* T (c)	*Eucryphia lucida* T (b)	*Eucryphia lucida* T (c)	*Nothofagus cunninghamii* T (b)
Rhizogonium distichum	119	-	-	-	-	-	-	-	-	-	-	-
Rhizogonium novaehollandiae	409	-0.0006	-0.0006	-0.0008	-	+0.0002	+0.0000	+0.0000	-	-	-	ns
Riccardia crassa	121	-	-	-	-	-	-	-	-	-	-	-
Rosulabryum billardieri var. *billardieri* (Schwägr.) Spence	120	-	-	-	-	-	-	-	-	-	-	-
Schistochila lehmanniana	122	-	-	-	-	-	-	-	-	-	-	-
Warburgiella leucocytus (Müll.Hal.) Tan, Schofield & Ramsay	260	-	-	ns	-	-0.0037	ns	-	-	-	-	+0.0128
Telaranea patentissima	301	-0.0061	ns	-0.0026	-	ns	-0.0032	ns	-	-	-	ns
Trichocolea mollissima	144	-	-	-	-	-	-	-	-	-	-	-
Tylimanthus diversifolius Hodgs.	123	-	-	-	-	-	-	-	-	-	-	-
Wijkia extenuata	558	ns	ns	ns	-	-0.0000	-0 0016	-0.0483	-	-	-	ns
Zoopsis argentea	267	-	-	-0 0055	-	+0.0000	ns	+0.0100	-	-	-	ns
Rhaphidorrhynchium amoenum	284	ns	ns	ns	-	ns	-0.0190	ns	-	-	-	ns
Kurzia hippurioides aff.	129	-	-	-	-	-	-	-	-	-	-	-
Campylopus introflexus	112	-	-	-	-	-	-	-	-	-	-	-
Cyathophorum bulbosum	219	-	-	-	-	-0.0352	-	-	-	-	-	-
Chiloscyphus semiteres	200	-	-	-	-	-	-	-	-	-	-	-
Dicranoloma billardieri	287	-0.0327	ns	-0 0036	-	-0 0081	ns	-0.0268	-	-	-	ns
Hypnum cupressiforme	182	-	-	-	-	-	-	-	-	-	-	-
Leptotheca gaudichaudii	347	-0.0110	-0.0401	ns	-	-0.0072	-0.0051	ns	-	-	-	ns
Thuidium sparsum	116	-	-	-	-	-	-	-	-	-	-	-

Species	Total occurrence of species	*Nothofagus cunninghamii* T (c)	*Olearia argophylla* T (b)	*Nematolepis squamea* ssp. *squamea* T (b)	*Pomaderris apetala* T (b)	*Anodopetalum biglandulosum* S (c)	*Atherosperma moschatum* S (b)	*Atherosperma moschatum* S (c)	*Nothofagus cunninghamii* S (b)	*Nematolepis squamea* ssp. *squamea* S (b)	*Phyllocladus asplenifolius* S (b)
Achrophyllum dentatum	214	-0 0052	-	-	-	-	-	-	-	-	-
Balantiopsis diplophylla	107	-	-	-	-	-	-	-	-	-	-
Bazzania involuta	631	+0 0000	-0.0006	-0.0013	-0.0000	ns	-0 0029	-0 0052	-0.0006	-0 0029	-0.0041
Bazzania monilinervis	115	-	-	-	-	-	-	-	-	-	-
Chiloscyphus echinellus	224	+0.0000	-	-	-	-	-	-	-	-	-
Dicranoloma menziesii	445	+0.0000	ns	ns	ns	-	-	-	ns	-	ns
Dicranoloma robustum	144	-	-	-	-	-	-	-	-	-	-
Dicranoloma robustum var. *setosum*	194	ns	-	-	-	-	-	-	-	-	-
Gackstroemia weindorferi	217	ns	-	-	-	-	-	-	-	-	-
Heteroscyphus coalitus	391	-0.0068	ns	-	ns	-	-	-	ns	-	-0.0206
Heteroscyphus fissistipus	372	-0.0036	ns	-	+0.0052	-	-	-	ns	-	-
Hymenophyton flabellatum	111	-	-	-	-	-	-	-	-	-	-
Hypnum chrysogaster	297	ns	-	-	ns	-	-	-	ns	-	-
Kurzia hippurioides	142	-	-	-	-	-	-	-	-	-	-
Lepidozia laevifolia	154	-	-	-	-	-	-	-	-	-	-
Lepidozia procera	164	-	-	-	-	-	-	-	-	-	-
Lepidozia ulothrix	544	ns	ns	ns	-0 0007	-	-	-0.0049	ns	-	-0 0253
Leucobryum candidum	191	ns	-	-	-	-	-	-	-	-	-
Lopidium concinnum	120	-	-	-	-	-	-	-	-	-	-
Metzgeria decipiens	213	ns	-	-	-	-	-	-	-	-	-
Plagiochila fasciculata	105	-	-	-	-	-	-	-	-	-	-
Ptychomnion aciculare	493	-0 0002	+0.0007	ns	+0 0000	-	-	-0.0121	-0.0005	-	ns
Radula buccinifera	144	-	-	-	-	-	-	-	-	-	-

Species	Total occurrence of species	*Nothofagus cunninghamii* T (c)	*Olearia argophylla* T (b)	*Nematolepis squamea* ssp. *squamea* T (b)	*Pomaderris apetala* T (b)	*Anodopetalum biglandulosum* S (c)	*Atherosperma moschatum* S (b)	*Atherosperma moschatum* S (c)	*Nothofagus cunninghamii* S (b)	*Nematolepis squamea* ssp. *squamea* S (b)	*Phyllocladus asplenifolius* S (b)
Rhizogonium distichum	119	-	-	-	-	-	-	-	-	-	-
Rhizogonium novaehollandiae	409	ns	-0.0237	-0.0213	-0 0008	-	-	-	-0 0002	-	-0.0154
Riccardia crassa	121	-	-	-	-	-	-	-	-	-	-
Rosulabryum billardieri var. *billardieri*	120	-	-	-	-	-	-	-	-	-	-
Schistochila lehmanniana	122	-	-	-	-	-	-	-	-	-	-
Warburgiella leucocytus	260	ns	-	-	-	-	-	-	ns	-	-
Telaranea patentissima	301	-0.0231	-	-	-0.0076	-	-	-	ns	-	-
Trichocolea mollissima	144	-	-	-	-	-	-	-	-	-	-
Tylimanthus diversifolius	123	-	-	-	-	-	-	-	-	-	-
Wijkia extenuata	558	ns	ns	ns	ns	-	-	ns	-0.0209	-	ns
Zoopsis argentea	267	ns	-	-	-	-	-	-	-0.0066	-	-
Rhapidorrhynchium amoenum	284	ns	-	-	-	-	-	-	ns	-	-
Kurzia hippuroides aff.	129	-	-	-	-	-	-	-	-	-	-
Campylopus introflexus	112	-	-	-	-	-	-	-	-	-	-
Cyathophorum bulbosum	219	ns	-	-	-	-	-	-	-	-	-
Chiloscyphus semiteres	200	-0.0270	-	-	-	-	-	-	-	-	-
Dicranoloma billardieri	287	ns	-	-	-	-	-	-	-0.0180	-	-
Hypnum cupressiforme	182	ns	-	-	-	-	-	-	-	-	-
Leptotheca gaudichaudii	347	+0.0000	ns	-	-0 0031	-	-	-	ns	-	-
Thuidium sparsum	116	-	-	-	-	-	-	-	-	-	-

Species	Total occurrence of species	*Pomaderris apetala* S (b)	*Montoca glauca* H (b)	*Dicksonia antarctica* fallen (b)	*Dicksonia antarctica* fallen (c)	*Dicksonia antarctica* (b)	*Dicksonia antarctica* (c)	Log (a)	Log (b)	Log (c)	Fallen branch (a)	Fallen branch (b)	Fallen branch (c)	Ground (a)	Ground (b)
Achrophyllum dentatum	214	-	-	-	-	ns	-	-	+0 0000	+0 0000	-	ns	+0.0354	-	+0 0000
Balantiopsis diplophylla	107	-	-	-	-	-	-	-	ns	-	-	-0.0481	-	-	+0.0000
Bazzania involuta	631	-0.0000	ns	ns	+0.0393	ns	+0.0001	-0.0006	+0 0000	+0.0000	-0.0000	ns	+0 0002	-0.0006	ns
Bazzania monilinervis	115	-	-	-	-	-	-	-	ns	-	-	-0.0107	-	-	ns
Chiloscyphus echinellus	224	-	-	-	-	+0.0000	+0.0000	-	ns	+0.0000	-	ns	+0.0011	-	ns
Dicranoloma menziesii	445	ns	-0 0496	ns	ns	-0.0215	+0.0070	ns	ns	+0 0000	-0.0349	ns	+0.0000	ns	ns
Dicranoloma robustum	144	-	-	-	-	-	-	-	+0.0000	-	-	+0.0356	-	-	+0.0000
Dicranoloma robustum var. *setosum*	194	-	-	-	-	ns	-	-	+0.0000	+0 0034	-	ns	+0 0138	-	ns
Gackstroemia weindorferi	217	-	-	-	-	-0 0023	ns	-	+0.0000	+0 0000	-	+0 0026	ns	-	ns
Heteroscyphus coalitus	391	ns	-	+0.0003	-	+0 0047	ns	-0.0083	+0.0000	+0 0057	-0.0042	+0.0003	+0 0057	-0.0017	+0.0000
Heteroscyphus fissistipus	372	+0.0000	-	ns	-	ns	-0.0173	-0.0442	+0.0373	+0.0001	-	+0 0029	ns	-0 0118	+0.0000
Hymenophyton flabellatum	111	-	-	-	-	-	-	-	ns	-	-	ns	-	-	ns
Hypnum chrysogaster	297	ns	-	ns	-	ns	ns	-	+0 0002	+0 0000	-	+0.0022	+0.0000	-	+0.0062
Kurzia hippurioides	142	-	-	-	-	-	-	-	+0.0312	-	-	ns	-	-	+0.0000
Lepidozia laevifolia	154	-	-	-	-	ns	-	-	+0.0000	-	-	ns	-	-	+0.0022
Lepidozia procera	164	-	-	-	-	-0 0364	-	-	+0 0000	-	-	ns	-	-	+0 0000
Lepidozia ulothrix	544	-0.0000	ns	ns	-0.0157	-0 0025	ns	-0 0236	+0.0000	+0.0000	-0 0010	+0 0000	+0 0001	-0.0236	+0 0027
Leucobryum candidum	191	-	-	-	-	ns	-	-	+0.0000	+0 0000	-	ns	ns	-	ns
Lopidium concinnum	120	-	-	-	-	-	-	-	ns	-	-	ns	-	-	ns
Metzgeria decipiens	213	-	-	-	-	ns	-	-	-0 0255	ns	-	ns	+0.0339	-	-0.0096
Plagiochila fasciculata	105	-	-	-	-	-	-	-	ns	-	-	ns	-	-	ns
Ptychomnion aciculare	493	+0.0002	-0.0237	ns	ns	ns	ns	ns	+0.0000	+0.0000	-0.0032	+0.0214	+0 0026	ns	+0.0000
Radula buccinifera	144	-	-	-	-	-	-	-	ns	-	-	ns	-	-	ns
Rhizogonium distichum	119	-	-	-	-	-	-	-	+0.0000	-	-	ns	-	-	ns

Species	Total occurrence of species	*Pomaderris apetala* S (b)	*Montoca glauca* H (b)	*Dicksonia antarctica* fallen (b)	*Dicksonia antarctica* fallen (c)	*Dicksonia antarctica* (b)	*Dicksonia antarctica* (c)	Log (a)	Log (b)	Log (c)	Fallen branch (a)	Fallen branch (b)	Fallen branch (c)	Ground (a)	Ground (b)
Rhizogonium novaehollandiae	409	-0 0006	-0.0042	ns	-	ns	+0.0000	-0.0237	+0.0000	+0.0000	-0 0154	-0 0247	ns	-0.0058	+0 0011
Riccardia crassa	121	-	-	-	-	-	-	-	+0.0000	-	-	+0 0000	-	-	+0 0013
Rosulabryum billardieri var. *billardieri*	120	-	-	-	-	-	-	-	+0.0190	-	-	ns	-	-	+0.0000
Schistochila lehmanniana	122	-	-	-	-	-	-	-	+0.0000	-	-	ns	-	-	+0.0000
Warburgiella leucocytus	260	-	-	-	-	-0.0265	-0 0177	-	+0.0005	+0.0021	-	+0.0000	+0 0000	-	ns
Telaranea patentissima	301	-0.0061	-	ns	-	ns	ns	-	+0.0000	+0.0000	-	+0.0000	+0.0000	-	+0.0000
Trichocolea mollissima	144	-	-	-	-	-	-	-	ns	-	-	ns	-	-	ns
Tylimanthus diversifolius	123	-	-	-	-	-	-	-	ns	-	-	ns	-	-	ns
Wijkia extenuata	558	ns	ns	ns	ns	ns	ns	-0 0178	+0.0000	+0 0000	-0.0000	+0.0050	+0.0025	-0.0044	+0 0000
Zoopsis argentea	267	-	-	-	-	ns	ns	-	+0 0000	+0.0000	-	ns	ns	-	+0 0000
Rhapidorrhynchium amoenum	284	ns	-	-	-	ns	-0 0358	-	+0.0000	+0.0000	-	+0.0000	+0.0019	-	+0.0196
Kurzia hippurioides aff	129	-	-	-	-	-	-	-	+0 0001	-	-	ns	-	-	+0.0006
Campylopus introflexus	112	-	-	-	-	-	-	-	ns	-	-	-0 0119	-	-	ns
Cyathophorum bulbosum	219	-	-	-	-	+0.0002	+0.0000	-	ns	+0 0137	-	ns	ns	-	ns
Chiloscyphus semiteres	200	-	-	-	-	-0.0439	-	-	+0.0000	+0 0187	-	+0 0000	ns	-	+0.0210
Dicranoloma billardieri	287	ns	-	-	-	-0.0002	ns	-	+0.0000	+0 0000	-	+0.0035	ns	-	+0 0000
Hypnum cupressiforme	182	-	-	-	-	ns	-	-	ns	+0 0015	-	ns	+0 0000	-	ns
Leptotheca gaudichaudii	347	-0.0110	-	+0.0401	-	+0.0001	+0.0000	ns	+0.0000	+0.0000	-	ns	ns	-0.0184	ns
Thuidium sparsum	116	-	-	-	-	-	-	-	ns	-	-	+0.0442	-	-	+0.0001

Species	Total occurrence of species	Ground (c)	Upturned root base (a)	Upturned root base (b)	Upturned root base (c)	Stump (a)	Stump (b)	Stump (c)	Roots (b)	Roots (c)	Rock (a)	Rock (b)	Rock (c)	Dead tree (b)	Dead tree (c)
Achrophyllum dentatum	214	+0.0000	-	-0 0256	-	-	-0.0262	-	ns	ns	-	ns	-	-0.0402	-
Balantiopsis diplophylla	107	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bazzania involuta	631	+0.0000	-0.0195	ns	ns	ns	+0.0325	+0.0024	ns	+0.0005	-0 0002	-0 0049	ns	ns	+0 0459
Bazzania monilinervis	115	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chiloscyphus echinellus	224	+0.0047	-	-0 0205	-	-	-0.0497	-	ns	+0 0000	-	-0.0206	-	-0.0098	-
Dicranoloma menziesii	445	+0.0000	-	-0.0001	ns	ns	-0 0105	ns	ns	+0 0000	-	ns	ns	-0 0374	ns
Dicranoloma robustum	144	-	-	-	-	-	ns	-	-	-	-	-	-	-	-
Dicranoloma robustum var *setosum*	194	ns	-	ns	-	-	+0 0003	-	-0.0351	-	-	ns	-	ns	-
Gackstroemia weindorferi	217	ns	-	ns	-	-	ns	-	ns	ns	-	ns	-	ns	-
Heteroscyphus coalitus	391	+0.0000	-	ns	ns	-0 0112	-0.0041	ns	+0 0186	+0.0073	-	+0 0002	ns	-0.0030	-0.0242
Heteroscyphus fissistipus	372	+0.0000	-	-0 0004	ns	-0 0033	-0.0029	ns	ns	ns	-	+0 0010	+0.0022	ns	-0.0338
Hymenophyton flabellatum	111	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypnum chrysogaster	297	+0.0126	-	ns	-	-	-0.0016	-	ns	+0.0101	-	ns	ns	ns	ns
Kurzia hippurioides	142	-	-	-	-	-	ns	-	-	-	-	-	-	-	-
Lepidozia laevifolia	154	-	-	-	-	-	ns	-	-	-	-	ns	-	-	-
Lepidozia procera	164	-	-	-	-	-	ns	-	-	-	-	ns	-	ns	-
Lepidozia ulothrix	544	+0.0015	-	ns	ns	-0 0003	+0.0037	+0.0337	ns	+0 0005	-	ns	ns	ns	ns
Leucobryum candidum	191	+0.0000	-	ns	-	-	ns	-	ns	-	-	-0.0488	-	ns	-
Lopidium concinnum	120	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Metzgeria decipiens	213	ns	-	-0 0070	-	-	-0.0029	-	ns	+0.0159	-	-0.0087	-	-0.0412	-
Plagiochila fasciculata	105	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ptychomnion aciculare	493	+0.0000	-	-0 0021	-0.0397	ns	-0.0119	ns	ns	+0.0456	-	+0.0160	-0 0414	ns	-0.0005
Radula buccinifera	144	-	-	-	-	-	-0 0268	-	-	-	-	-	-	-	-
Rhizogonium distichum	119	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhizogonium novaehollandiae	409	+0.0010	-	ns	ns	ns	+0.0001	+0.0071	-0.0016	ns	-	-0.0006	-0.0240	ns	ns
Riccardia crassa	121	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rosulabryum billardieri var. *billardieri*	120	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Species	Total occurrence of species	Ground (c)	Upturned root base (a)	Upturned root base (b)	Upturned root base (c)	Stump (a)	Stump (b)	Stump (c)	Roots (b)	Roots (c)	Rock (a)	Rock (b)	Rock (c)	Dead tree (b)	Dead tree (c)
Schistochila lehmanniana	122	-	-	-	-	-	ns	-	-	-	-	-	-	-	-
Warburgiella leucocytus	260	ns	-	-0.0292	-	-	ns	-	ns	ns	-	ns	ns	ns	-
Telaranea patentissima	301	+0.0000	-	ns	-	-	ns	-	ns	ns	-	ns	ns	ns	-0.0076
Trichocolea mollissima	144	-	-	-	-	-	-0.0268	-	-	-	-	-	-	-	-
Tylimanthus diversifolius	123	-	-	-	-	-	ns	-	-	-	-	-	-	-	-
Wijkia extenuata	558	+0.0025	-	-0.0031	ns	-0.0002	ns	ns	ns	+0.0033	-	+0.0080	ns	ns	ns
Zoopsis argentea	267	+0 0000	-	ns	-	-	ns	-	ns	ns	-	-0.0017	ns	ns	-
Rhapidorrhynchium amoenum	284	ns	-	ns	-	-	-0.0008	-	ns	ns	-	+0.0015	ns	ns	-
Kurzia hippurioides aff.	129	-	-	-	-	-	ns	-	-	-	-	-	-	-	-
Campylopus introflexus	112	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyathophorum bulbosum	219	ns	-	ns	-	-	ns	-	ns	ns	-	ns	-	ns	-
Chiloscyphus semiteres	200	-0.0237	-	ns	-	-	ns	-	ns	-	-	ns	-	ns	-
Dicranoloma billardieri	287	+0 0253	-	ns	-	-	ns	-	ns	ns	-	ns	ns	ns	-
Hypnum cupressiforme	182	ns	-	-	-	-	-0.0081	-	ns	-	-	ns	-	ns	-
Leptotheca gaudichaudii	347	ns	-	ns	-	ns	+0.0015	-	-0.0268	ns	-	ns	ns	ns	ns
Thuidium sparsum	116	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*Appendix 8.8. R values from pairwise comparisons of substrate/age classes (species compostion data) using ANOSIM. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, ns = not significant. Number of sites (n) in age class: age class a, 1-18 years, n = 18; age class b 31-67 years, n = 54; age class c, > 110 years, n = 33. n/a = not applicable.*

Substrate			*Acacia dealbata*	*Acacia melanoxylon*	*Atherosperma moschatum*	*Eucalyptus delegatensis*	*Eucalyptus obliqua*	*Eucalyptus obliqua*	*Eucalyptus regnans*	*Eucalyptus regnans*	*Eucryphia lucida*	*Eucryphia lucida*
	Lifeform		Tree	Tree	Tree	Tree	Tree	Tree	Tree	Tree	Tree	Tree
		Age class	b	b	b	b	b	c	b	c	b	c
Acacia melanoxylon	Tree	b	0.1308**									
Atherosperma moschatum	Tree	c	0.501***	0.4883***								
Eucalyptus delegatensis	Tree	b	0.6618***	0.4303***	0.8503***							
Eucalyptus obliqua	Tree	b	0 7876***	0 6674***	0 8456***	0.2694**						
Eucalyptus obliqua	Tree	c	0.8428***	0 7134***	0.8781***	0 469***	0.077*					
Eucalyptus regnans	Tree	b	0.7331***	0 5784***	0.8639***	0.1204ns	0.0774*	0 2318***				
Eucalyptus regnans	Tree	c	0 7224***	0.5236***	0.8493***	0.3091**	0.0626ns	-0.0285ns	0 2641**			
Eucryphia lucida	Tree	b	0.2258**	0.0983ns	0.3606***	0 3574***	0 6785***	0.748***	0 6455***	0 4274**		
Eucryphia lucida	Tree	c	0 4579***	0 2797***	0.2464**	0.5643***	0.7347***	0.7652***	0.7425***	0.4356***	0.0434ns	
Nothofagus cunninghamii	Tree	b	0.426***	0.273***	0 2694***	0 3628***	0 4484***	0 488***	0 4292***	0 3802***	0 1303ns	0 2104*
Nothofagus cunninghamii	Tree	c	0.8231***	0.7039***	0.4354***	0.7252***	0.6382***	0 5826***	0.6664***	0.6748***	0.5635***	0.5447***
Olearia argophylla	Tree	b	0.0206ns	0 142**	0 3398***	0 7242***	0.8027***	0.8803***	0.7587***	0.785***	0.3071**	0.426***
Nematolepis squamea ssp *squamea*	Tree	b	0.1749**	-0.0345ns	0 4239***	0 3527***	0.6363***	0.7304***	0.5702***	0 5079***	-0.0195ns	0.1665*
Pomaderris apetala	Tree	b	0.0823*	0 2764***	0 4019***	0 9063***	0 8701***	0.9713***	0.902***	0.885***	0 4897***	0 6***
Anodopetalum biglandulosum	Tall shrub	c	0 4843***	0.3032***	0 2077*	0.642***	0.7454***	0.8246***	0.76***	0.6544***	0.092*	-0.0166ns
Atherosperma moschatum	Tall shrub	b	0 1715*	0.0317ns	0.3071***	0.4868***	0.7737***	0.8511***	0.7313***	0.5669***	-0.0366ns	0.0818ns
Atherosperma moschatum	Tall shrub	c	0.4857***	0 2975**	0.1868*	0.7498***	0 8486***	0.891***	0.8528***	0.759***	0.1982*	0.0804ns
Nothofagus cunninghamii	Tall shrub	b	0.2485***	0.1558**	0 3023***	0.3255***	0.5439***	0.5867***	0.497***	0 4346***	0 0138ns	0.1949**
Nematolepis squamea ssp *squamea*	Tall shrub	b	0 104ns	0 0034ns	0.5436***	0.4006***	0 7639***	0 8422***	0.6937***	0.5784***	-0.085ns	0.1859*
Phyllocladus asplenifolius	Tall shrub	b	0 2401**	0.0091ns	0.4936***	0.3784***	0.6353***	0 6768***	0.5932***	0.4599***	0.0291ns	0.1982**
Pomaderris apetala	Tall shrub	b	0.0876*	0.2684***	0.3461***	0 9187***	0 8718***	0.9706***	0.9055***	0.9184***	0 493***	0 6183***
Monotoca glauca	Short shrub	b	0.4712***	0.2581***	0 6692***	0 3598***	0.5474***	0 6293***	0 5098***	0 4482***	0 1386*	0.4378***
Dicksonia antarctica (horizontal, dead)	Treefern	b	0 5373***	0.2701***	0.6347***	0.3587***	0.4181***	0.4934***	0.3302***	0.4126***	0 4412***	0.5098***
Dicksonia antarctica (horizontal, dead)	Treefern	c	0 6394***	0.3734***	0.5624***	0.5214***	0 5338***	0.5232***	0.4891***	0.4468***	0.4975***	0 4888***

Substrate			*Acacia dealbata*	*Acacia melanoxylon*	*Atherosperma moschatum*	*Eucalyptus delegatensis*	*Eucalyptus obliqua*	*Eucalyptus obliqua*	*Eucalyptus regnans*	*Eucalyptus regnans*	*Eucryphia lucida*	*Eucryphia lucida*
	Lifeform		Tree	Tree	Tree	Tree	Tree	Tree	Tree	Tree	Tree	Tree
		Age class	b	b	b	b	b	c	b	c	b	c
Dicksonia antarctica (vertical, alive)	Treefern	b	0.438***	0.3602***	0.4798***	0.3581***	0.3017***	0 333***	0.279***	0.3119***	0 4311***	0.5265***
Dicksonia antarctica (vertical, alive)	Treefern	c	0.7707***	0.6314***	0.5437***	0 7109***	0.5842***	0 5477***	0.5908***	0.6306***	0.6877***	0.6928***
Log	n/a	a	0 691***	0 5455***	0.883***	0 82***	0 856***	0.938***	0 8437***	0.8868***	0.7472***	0.8356***
Log	n/a	b	0 896***	0 8313***	0.8797***	0.8546***	0.7792***	0 8992***	0.7781***	0 9522***	0 9109***	0.918***
Log	n/a	c	0.8257***	0.7245***	0.7349***	0 9338***	0 8195***	0.9303***	0 8483***	0 958***	0.8328***	0.8481***
Branch	n/a	a	0 6114***	0.4772***	0.8295***	0.7285***	0.8498***	0.9085***	0.8266***	0.7892***	0.5648***	0 6844***
Branch	n/a	b	0.5417***	0.5113***	0.6137***	0 5554***	0.5573***	0.6795***	0.5394***	0.732***	0.5565***	0.6899***
Branch	n/a	c	0.7268***	0 6312***	0.4414***	0 9095***	0 7947***	0.8821***	0.8442***	0 933***	0.6494***	0.6232***
Ground	n/a	a	0 7836***	0 6527***	0.9357***	0.9006***	0.8872***	0.9605***	0 8908***	0 932***	0.8261***	0.8867***
Ground	n/a	b	0 8334***	0 7719***	0.8743***	0.8075***	0.7456***	0.8733***	0 7475***	0.9215***	0.8795***	0.8832***
Ground	n/a	c	0.8329***	0.7141***	0 777***	0.9071***	0.7765***	0.9033***	0.8196***	0.9394***	0 8261***	0 8158***
Upturned tree root	n/a	a	0.7758***	0.6097***	0.9362***	0 7548***	0.8133***	0 8824***	0 8244***	0.7401***	0.6654***	0.7586***
Upturned tree root	n/a	b	0.475***	0.3289***	0.5396***	0.007ns	0 1884***	0.2361***	0.0673*	0.0863ns	0.2967**	0.3227***
Upturned tree root	n/a	c	0.5405***	0.2899***	0 5534***	0.335***	0.4692***	0 5041***	0 4613***	0.2673**	0.1844*	0.2855***
Stump	n/a	a	0.7081***	0.5155***	0.8618***	0 6135***	0 7083***	0.7384***	0 6549***	0.6448***	0.6828***	0.762***
Stump	n/a	b	0.7273***	0 6189***	0.6924***	0.145ns	0.0782*	0.1319**	0.0402ns	0 1396ns	0.5919***	0.65***
Stump	n/a	c	0.6339***	0.4074***	0.541***	0.311**	0 2561***	0.2602***	0.2861***	0 2001*	0.4066***	0.4578***
Roots	n/a	b	0.1749***	0.077*	0 3421***	0.297***	0.3711***	0 4172***	0.3383***	0 3378***	0 1272*	0 2707**
Roots	n/a	c	0 7135***	0 5485***	0.3994***	0 7901***	0.6269***	0.6949***	0.7032***	0 767***	0.5657***	0.5853***
Rock	n/a	a	0.6945***	0.5118***	0 9474***	0.8259***	0.8978***	0 9726***	0.8733***	0.839***	0.6429***	0.7972***
Rock	n/a	b	0 3183***	0.2316**	0.4441***	0.4633***	0.5245***	0 6081***	0.4991***	0 57***	0 3741**	0 454***
Rock	n/a	c	0 4517***	0.1946***	0 4528***	0.5396***	0.5814***	0 6173***	0.582***	0.5***	0 226**	0 3403***
Dead tree	n/a	b	0.3317***	0.2586***	0.4047***	0.0362ns	0.108**	0.1364**	0 045ns	0.0584ns	0.2057**	0.3106***
Dead tree	n/a	c	0 5184***	0 3125***	0.4156***	0.2647**	0.3773***	0.3097***	0 3661***	0.0788ns	0.2091*	0.2022*

Substrate			*Nothofagus cunninghamii*	*Nothofagus cunninghamii*	*Olearia argophylla*	*Nematolepis squamea* ssp *squamea*	*Pomaderris apetala*	*Anodopetalum biglandulosum*	*Atherosperma moschatum*	*Atherosperma moschatum*	*Nothofagus cunninghamii*
	Lifeform		Tree	Tree	Tree	Tree	Tree	Tall shrub	Tall shrub	Tall shrub	Tall shrub
		Age class	b	c	b	b	b	c	b	c	b
Nothofagus cunninghamii	Tree	c	0 1788***								
Olearia argophylla	Tree	b	0 3644***	0 7713***							
Nematolepis squamea ssp *squamea*	Tree	b	0.1493*	0.5983***	0.2134**						
Pomaderris apetala	Tree	b	0.5606***	0.9033***	0.0813*	0.3353***					
Anodopetalum biglandulosum	Tall shrub	c	0 0709ns	0 3408***	0.491***	0.2139**	0.7097***				
Atherosperma moschatum	Tall shrub	b	0.2422**	0.7242***	0.1758*	0.0064ns	0.3783***	0.224**			
Atherosperma moschatum	Tall shrub	c	0.2762***	0.6241***	0.5084***	0.2089**	0.6059***	0.1601*	0.1157ns		
Nothofagus cunninghamii	Tall shrub	b	0.0589*	0.4045***	0.2625***	0.0161ns	0 3601***	0.1386ns	0.0649ns	0.1357*	
Nematolepis squamea ssp *squamea*	Tall shrub	b	0 2544**	0.7563***	0 2184**	-0.0783ns	0 3747***	0 2607**	-0.0711ns	0.2898***	0.079ns
Phyllocladus asplenifolius	Tall shrub	b	0.1926**	0.6537***	0.3028***	-0.047ns	0.4352***	0.24**	-0 0067ns	0.2067**	0 0091ns
Pomaderris apetala	Tall shrub	b	0.521***	0.8753***	0.0566*	0.3284***	0.0214ns	0.6929***	0 3583**	0.5966***	0.3138***
Monotoca glauca	Short shrub	b	0.1608**	0.5826***	0 5358***	0 1633**	0.7655***	0.4154***	0.3768***	0 5604***	0.1059*
Dicksonia antarctica (horizontal, dead)	Treefern	b	0.192***	0 4819***	0.4582***	0 2806***	0 7008***	0.4829***	0 4444***	0.63***	0 3118***
Dicksonia antarctica (horizontal, dead)	Treefern	c	0.237***	0.3536***	0.6254***	0.4412***	0.8616***	0.6248***	0.462***	0 6235***	0.2687***
Dicksonia antarctica (vertical, alive)	Treefern	b	0.2333***	0.3528***	0.3233***	0 3356***	0.4498***	0.4898***	0 3709***	0.5466***	0.3184***
Dicksonia antarctica (vertical, alive)	Treefern	c	0.3254***	0 1933***	0 7053***	0.647***	0.8563***	0.6907***	0.7094***	0 74***	0.45***
Log	n/a	a	0.68***	0 8958***	0.7483***	0 6534***	0.8926***	0 8496***	0.766***	0.8799***	0 6022***
Log	n/a	b	0.649***	0 7004***	0.8285***	0.8178***	0.9342***	0.8121***	0.919***	0.9644***	0 8***
Log	n/a	c	0.541***	0.5674***	0.7602***	0.7807***	0.9074***	0.7211***	0.8801***	0.9197***	0.6481***
Branch	n/a	a	0 6183***	0 8739***	0.7289***	0 5329***	0 8385***	0.6481***	0.591***	0.74***	0 4769***
Branch	n/a	b	0.2641***	0.4295***	0.3955***	0.4089***	0 5501***	0.5057***	0.5787***	0.7529***	0.4776***
Branch	n/a	c	0.306***	0.3797***	0 5607***	0 6206***	0.7283***	0.3973***	0.7104***	0.7378***	0 5194***
Ground	n/a	a	0.7525***	0 9458***	0.8593***	0.7361***	0.9406***	0.9225***	0.8299***	0.9089***	0.6551***
Ground	n/a	b	0 6381***	0.7255***	0 7319***	0 7427***	0.8499***	0.7946***	0 8562***	0 9554***	0.7805***
Ground	n/a	c	0.5694***	0.6585***	0.7811***	0.7607***	0 8981***	0.7477***	0.8567***	0 9196***	0.6563***
Upturned tree root	n/a	a	0.7447***	0 9293***	0 8854***	0 6571***	0 9354***	0 849***	0.6919***	0 8318***	0.5939***
Upturned tree root	n/a	b	0 1403**	0 3944***	0.3826***	0 234***	0 5899***	0.2439**	0 3454***	0.4981***	0 2895***
Upturned tree root	n/a	c	0.1206**	0.4702***	0.5121***	0.1775***	0.7038***	0.2808***	0 2813***	0.391***	0.1993**
Stump	n/a	a	0.631***	0.8052***	0.7587***	0.6026***	0.8833***	0.8129***	0.7059***	0 8405***	0.5828***
Stump	n/a	b	0 3141***	0.3323***	0.6277***	0.521***	0 7899***	0.5551***	0.6463***	0.7517***	0 5181***
Stump	n/a	c	0.0839*	0 2004***	0 5836***	0.3582***	0.7878***	0.4936***	0.5182***	0.5882***	0.2229***
Roots	n/a	b	0.076*	0.3952***	0.0933*	0.01ns	0.2241***	0 245**	0.1262ns	0.3262***	0.123**
Roots	n/a	c	0.187***	0 2531***	0.5732***	0.4994***	0.745***	0.471***	0.6362***	0 6174***	0.3516***
Rock	n/a	a	0.7461***	0.9837***	0.8284***	0.6121***	0.9218***	0.8603***	0 6501***	0.8485***	0 5749***
Rock	n/a	b	0.2307***	0.4928***	0 1676**	0 2072*	0.3471***	0.3833**	0 3007**	0.4711***	0.3278***
Rock	n/a	c	0.144***	0.5043***	0.3595***	0.1608**	0.5187***	0.3255***	0.2297**	0 3575***	0.1931***
Dead tree	n/a	b	0.0927*	0.2757***	0.2298***	0.1555*	0.3646***	0.2195*	0 2628**	0.4478***	0 2369***
Dead tree	n/a	c	0 1029**	0 2816***	0.4868***	0.2339**	0 6584***	0 1844*	0 268**	0 3212***	0.1961***

Substrate			*Nematolepis squamea* ssp *squamea*	*Phyllocladus asplenifolius*	*Pomaderris apetala*	*Monotoca glauca*	*Dicksonia antarctica* (horizontal, dead)	*Dicksonia antarctica* (horizontal, dead)	*Dicksonia antarctica* (vertical, alive)	*Dicksonia antarctica* (vertical, alive)	Log	Log	Log
	Lifeform		Tall shrub	Tall shrub	Tall shrub	Short shrub	Treefern	Treefern	Treefern	Treefern	n/a	n/a	n/a
		Age class	b	b	b	b	b	c	b	c	a	b	c
Phyllocladus asplenifolius	Tall shrub	b	0 0189ns										
Pomaderris apetala	Tall shrub	b	0.4***	0.4136***									
Monotoca glauca	Short shrub	b	0 2219**	0.2289**	0.7673***								
Dicksonia antarctica (horizontal, dead)	Treefern	b	0.4463***	0 3887***	0 6972***	0.4347***							
Dicksonia antarctica (horizontal, dead)	Treefern	c	0.5896***	0 4496***	0.8719***	0.6334***	0.0069ns						
Dicksonia antarctica (vertical, alive)	Treefern	b	0.3992***	0 3995***	0 4284***	0.4444***	0.0512ns	-0.0024ns					
Dicksonia antarctica (vertical, alive)	Treefern	c	0 79***	0 6938***	0.8443***	0.737***	0.2919***	0.1171*	0.0549*				
Log	n/a	a	0.7309***	0.6961***	0.9023***	0.7432***	0.7413***	0.8894***	0 6831***	0 9078***			
Log	n/a	b	0.8869***	0 8764***	0.9132***	0.83***	0.5127***	0.6791***	0 5576***	0.6642***	0.8975***		
Log	n/a	c	0.8653***	0 8194***	0.8894***	0 8657***	0.5172***	0.6764***	0.4134***	0 6017***	0.9204***	0.1698***	
Branch	n/a	a	0 5768***	0 5636***	0.824***	0.6219***	0 7771***	0 8262***	0.7372***	0.9121***	0 1117*	0.953***	0.9297***
Branch	n/a	b	0.5104***	0.5204***	0.468***	0 3727***	0.3556***	0.533***	0.391***	0.5059***	0 7239***	0.2196***	0.2106***
Branch	n/a	c	0.729***	0.7037***	0.6606***	0.7461***	0 5193***	0.66***	0 4387***	0.573***	0 8706***	0 5383***	0.238***
Ground	n/a	a	0.8226***	0.7529***	0 9572***	0.8237***	0.8194***	0 9499***	0.756***	0 9549***	0 0651*	0.936***	0.9736***
Ground	n/a	b	0 8408***	0.8352***	0 8242***	0 8024***	0 4107***	0 6184***	0.4871***	0.6485***	0.8819***	0.1825***	0.2272***
Ground	n/a	c	0.8748***	0 8056***	0 896***	0.8514***	0.417***	0.5852***	0 3912***	0.5954***	0.9301***	0.3688***	0 1928***
Upturned tree root	n/a	a	0.7053***	0 6427***	0.9539***	0.7412***	0.8374***	0.8822***	0 7621***	0.9383***	0.2921**	0 9835***	0.9827***
Upturned tree root	n/a	b	0 2995***	0 3072***	0.5761***	0.145*	0.0235ns	-0.0038ns	0 2354***	0.267***	0 4081***	0.5823***	0.4447***
Upturned tree root	n/a	c	0.3297***	0 2002***	0.7211***	0.2303**	0.1209*	0 1703**	0.2747***	0 4732***	0.7362***	0.7799***	0 7314***
Stump	n/a	a	0 6775***	0.633***	0.8977***	0.6655***	0.5932***	0 6201***	0.572***	0 7709***	0.0507ns	0.9118***	0.919***
Stump	n/a	b	0.649***	0 5742***	0 7596***	0.3774***	0.1814***	0.1542*	0.2632***	0 2122***	0.6641***	0.4026***	0.4158***
Stump	n/a	c	0.5316***	0.3991***	0.8029***	0.3415***	0 1224**	0.1208*	0.076ns	0.1813***	0 8325***	0.6745***	0.6767***
Roots	n/a	b	0.0821ns	0 0882ns	0 1865**	0.1094*	0.0539ns	0.1378*	0 1567***	0.2995***	0 5194***	0 5738***	0.3963***
Roots	n/a	c	0 6796***	0.5638***	0.7304***	0.5778***	0.3297***	0.4005***	0 2087***	0 2878***	0.9076***	0 5467***	0 3628***
Rock	n/a	a	0.6411***	0.6206***	0 942***	0 7566***	0.8521***	0.9264***	0 7628***	0 9709***	0.1018ns	0 9889***	0 986***
Rock	n/a	b	0 3099**	0 2729***	0 2921***	0.3548***	0.1668**	0.3197***	0 2657***	0.4375***	0.5373***	0 4561***	0.3187***
Rock	n/a	c	0.3219***	0.1937***	0 4775***	0 3418***	0.1007*	0 1895**	0.2585***	0 4338***	0.7164***	0.6914***	0 5293***
Dead tree	n/a	b	0.2555**	0 1766**	0.3293***	0.1489*	0.0909*	0.0825ns	0.1849***	0 212***	0.4886***	0.4767***	0.3538***
Dead tree	n/a	c	0.3517***	0.2204**	0 6491***	0 2136**	0.2***	0 0955ns	0.2647***	0 3522***	0 701***	0.7903***	0.7214***

Substrate			Branch	Branch	Branch	Ground	Ground	Ground	Upturned tree root	Upturned tree root	Upturned tree root	Stump	Stump	Stump	Roots	Roots
	Lifeform		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
		Age class	a	b	c	a	b	c	a	b	c	a	b	c	b	c
Branch	n/a	b	0.7783***													
Branch	n/a	c	0 8465***	0.2009***												
Ground	n/a	a	0 3493***	0 8079***	0.9479***											
Ground	n/a	b	0.9438***	0 2649***	0.5003***	0.8879***										
Ground	n/a	c	0.9347***	0.3678***	0.4152***	0 9608***	0 1154***									
Upturned tree root	n/a	a	0 2176**	0.9206***	0.9711***	0.2515**	0 9677***	0 9703***								
Upturned tree root	n/a	b	0.4457***	0 4476***	0 4952***	0 473***	0 5417***	0.4037***	0.4451***							
Upturned tree root	n/a	c	0.7005***	0.4748***	0 6415***	0.764***	0.6623***	0.6059***	0 7042***	0.0133ns						
Stump	n/a	a	0.1009*	0.776***	0.9017***	0 2019***	0.8941***	0.9068***	0 0586ns	0.319***	0 6311***					
Stump	n/a	b	0 7744***	0 3488***	0.5238***	0.7256***	0.4953***	0.4774***	0.7664***	0.1605***	0 302***	0 5651***				
Stump	n/a	c	0 8071***	0 3646***	0.5445***	0.901***	0.6252***	0.6256***	0.8336***	0.0012ns	0 0957*	0.6214***	0.0366ns			
Roots	n/a	b	0.5424***	0.2632***	0.3325***	0.6059***	0.4877***	0.3679***	0.6477***	0 192***	0.0967*	0.4926***	0.3668***	0.0727ns		
Roots	n/a	c	0 9057***	0 2588***	0.2535***	0.9419***	0.4494***	0.3167***	0 9331***	0.3352***	0 3632***	0.8535***	0.358***	0 2551***	0.1375**	
Rock	n/a	a	0 0861ns	0.9135***	0.9838***	0.2071*	0.9825***	0.9855***	0.1109*	0 4684***	0.7769***	0.0457ns	0 843***	0.9123***	0.6355***	0.9785***
Rock	n/a	b	0.6248***	0.2164***	0.2844***	0.5697***	0.2518***	0.2718***	0.7189***	0.2778***	0 1895*	0.6012***	0.4331***	0.2922***	0 0803**	0.2148***
Rock	n/a	c	0.7125***	0.4206***	0.4731***	0 7572***	0 5171***	0 3939***	0 7661***	0 2214***	0.0157ns	0.6853***	0.4817***	0 2086***	0.0367ns	0.2297***
Dead tree	n/a	b	0.5586***	0 247***	0.32***	0 6059***	0.4638***	0.3944***	0.6706***	0.1039**	0.112*	0.4623***	0.1051**	-0 0461ns	0.1062**	0.2105***
Dead tree	n/a	c	0.6429***	0.5191***	0.5819***	0.7609***	0 7821***	0 7274***	0 6456***	0.115**	0.0664*	0 5581***	0.2489***	0.0283ns	0.1699**	0.4195***

Substrate			Rock	Rock	Rock	Dead tree
	Lifeform		n/a	n/a	n/a	n/a
		Age class	a	b	c	b
Rock	n/a	b	0 693***			
Rock	n/a	c	0 8013***	0.0909*		
Dead tree	n/a	b	0 6988***	0.2115***	0.2201***	
Dead tree	n/a	c	0.7245***	0.3393***	0.2106***	0.0871*

Appendix 8.9. Frequency of occurrence of bryophyte species and vascular plants in logging sites (n = 26), wildfire sites (n = 24) and all sites (n = 50). Species sorted by lifeform.

Bryophyte species	Logging	Wildfire	All sites
Acrocarpous moss			
Atrichum androgynum	19 23	8 33	14 00
Barbula calycina	0 00	12 50	6 00
Bryum crassum	0 00	4 17	2.00
Calyptopogon mnioides	19.23	4 17	12 00
Campylopus bicolor var *ericeticola*	11.54	0 00	6 00
Campylopus clavatus	3 85	0 00	2 00
Campylopus flindersii	7 69	4.17	6 00
Campylopus introflexus	19 23	29 17	24 00
Campylopus purpureocaulis Dusén	11 54	4 17	8 00
Campylopus pyriformis	11.54	4 17	8 00
Campylopus pyriformis var. a	3 85	8 33	6 00
Ceratodon purpureus	0 00	4 17	2 00
Dawsonia superba Grev var. *pulchera* Zant.	0 00	4 17	2 00
Dicranoloma billardieri	88 46	91 67	90.00
Dicranoloma dicarpum	65 38	66 67	66 00
Dicranoloma menziesii	88.46	91 67	90 00
Dicranoloma platycaulon	26 92	16 67	22 00
Dicranoloma robustum	42 31	75 00	58 00
Dicranoloma robustum var *setosum*	73 08	83 33	78 00
Ditrichum cylindricarpum	0 00	4 17	2 00
Ditrichum difficile	15 38	25 00	20.00
Fissidens pallidus	61 54	25 00	44.00
Fissidens pungens	19 23	12 50	16 00
Fissidens taylorii	11 54	8 33	10 00
Fissidens tenellus	57 69	50.00	54 00
Funaria hygrometrica	3 85	0 00	2 00
Goniobryum subbasilare	34 62	20 83	28.00
Hypnodendron comosum	15 38	16 67	16 00
Hypnodendron spinnervium ssp. *archeri*	38 46	45 83	42 00
Hypnodendron spp	11 54	4 17	8 00
Hypnodendron vitiense ssp *australe*	11.54	0 00	6 00
Leptostomum inclinans	15 38	29.17	22 00
Leptotheca gaudichaudii	92 31	95 83	94 00
Leucobryum candidum	57 69	45 83	52.00
Macrocoma tenue ssp *tenue*	3 85	4 17	4 00
Macromitrium archeri	50 00	45 83	48 00
Macromitrium ligulaefolium	3 85	0 00	2 00
Macromitrium microstomum	7 69	4 17	6 00
Mittenia plumula	34 62	25 00	30 00
Orthodontium lineare	57.69	66 67	62 00
Orthotrichum tasmanicum var *tasmanicum*	19 23	29.17	24 00
Pogonatum subulatum	3.85	4 17	4 00
Pohlia nutans	0 00	4 17	2 00
Polytrichum juniperinum	19 23	29 17	24.00
Ptychomitrium australe	7 69	0 00	4 00
Racomitrium crispulum var. *tasmanicum*	3 85	12 50	8.00
Rhizogonium distichum	73 08	37 50	56 00
Rhizogonium novaehollandiae	88 46	100 00	94 00
Rhizogonium pennatum var *aristatum*	3 85	0 00	2 00
Rosulabryum billardieri var *billardieri* (Schwagr) Spence	69 23	79 17	74 00
Rosulabryum campylothecium (Tayl) Spence	3.85	0 00	2 00
Ulota lutea	11.54	12.50	12 00
Ulota spp	7.69	4 17	6 00
Ulota viridis	15.38	8 33	12 00
Zygodon intermedius	42.31	50 00	46 00
Pleurocarpous moss			
Achrophyllum dentatum	84 62	58 33	72.00
Acrocladium chlamydophyllum	38 46	41 67	40 00
Brachythecium paradoxum	0 00	4 17	2 00
Calyptrochaeta apiculata	11 54	4 17	8 00
Camptochaete arbuscula	30 77	20 83	26 00
Camptochaete deflexa	3 85	4 17	4 00
Catagonium nitens (Brid) Cardot ssp. *nitens*	3 85	29 17	16.00
Brachythecium salebrosum (F. Weber & D Mohr) Schimp	3 85	4 17	4 00
Brachythecium salebrosum/ rutabulum	15 38	12 50	14 00
Cyathophorum bulbosum	69 23	62 50	66 00
Daltonia splachnoides	3 85	4.17	4 00
Distichophyllum crispulum	11 54	4.17	8 00
Distichophyllum microcarpum	11 54	8 33	10 00
Distichophyllum pulchellum	42 31	37.50	40 00
Glyphothecium sciuroides	26 92	25 00	26 00
Hypnum chrysogaster	65 38	83 33	74 00
Hypnum cupressiforme	80 77	70 83	76 00
Hypopterygium didictyon Mull Hal	3 85	4 17	4 00

Vascular plants	Logging	Wildfire	All sites
Tree			
Acacia dealbata	42 31	33 33	38 00
Acacia melanoxylon	26 92	33 33	30 00
Acacia riceana	11.54	4.17	8.00
Acacia verticillata	0 00	16 67	8 00
Atherosperma moschatum	30 77	25 00	28 00
Eucalyptus brookeriana	11 54	4 17	8 00
Eucalyptus obliqua	42.31	50 00	46 00
Eucalyptus regnans	50 00	41 67	46 00
Eucalytpus delegatensis ssp. *tasmaniensis*	23 08	25 00	24 00
Eucryphia lucida	30 77	37.50	34 00
Leptospermum scoparium	3 85	0 00	2.00
Leptospermum spp	0 00	12 50	6.00
Melaleuca squarrosa	3.85	4 17	4 00
Nothofagus cunninghamii	69 23	58 33	64 00
Phyllocladus asplenifolius	46 15	41.67	44 00
Tall shrub			
Anodopetalum biglandulosum	3 85	4 17	4 00
Anopterus glandulosus	15 38	20 83	18.00
Banksia marginata	0 00	4 17	2 00
Cassinia aculeata	3.85	0 00	2 00
Cenarrhenes nitida	7.69	25.00	16 00
Hakea lissosperma	0.00	4.17	2 00
Monotoca glauca	23 08	58 33	40 00
Monotoca linifolia	0.00	4 17	2 00
Notelaea ligustrina	7 69	0 00	4.00
Olearia argophylla	50 00	29 17	40.00
Nematolepis squamea ssp *squamea*	34.62	62.50	48 00
Pittosporum bicolor	15.38	16.67	16 00
Pomaderris apetala	57 69	41 67	50 00
Prostanthera lasianthos	3 85	4 17	4 00
Tasmannia lanceolata	23 08	25 00	24.00
Short shrub			
Bauera rubioides	0.00	4.17	2 00
Coprosma quadrifida	42 31	12.50	28 00
Correa lawrenciana	3 85	0 00	2 00
Cyathodes glauca	19 23	20.83	20 00
Cyathodes juniperina	23 08	20 83	22 00
Cyathodes parvifolia	3 85	0 00	2 00
Epacridaceae	0 00	4 17	2 00
Gaultheria hispida	0 00	16 67	8.00
Olearia persoonioides	0 00	12 50	6.00
Ortes diversifolia	0.00	4.17	2.00
Oxylobium ellipticum	0.00	4.17	2.00
Pimelea cinerea	3 85	4 17	4 00
Pimelea drupacea	3 85	12.50	8 00
Telopea truncata	3 85	0 00	2 00
Trochocarpa cunninghamii	3 85	20.83	12.00
Trochocarpa disticha	7 69	12 50	10 00
Trochocarpa gunnii	3 85	0 00	2 00
Non-woody angiosperm			
Acaena novae-zelandiae	3 85	0 00	2 00
Agrostis rudis	0 00	4 17	2.00
Carex spp.	3 85	0 00	2.00
Chloglottis pedunculata	0.00	4 17	2.00
Chiloglottis spp	3.85	16 67	10 00
Corybas spp.	3.85	0 00	2 00
Dianella tasmanica	0.00	25 00	12 00
Drmophila cyanacarpa	3.85	12.50	8 00
Gahnia grandis	61 54	41.67	52 00
Gahnia spp.	0 00	4.17	2 00
Hydrocotyle hirta	11 54	8 33	10 00
Hydrocotyle sp. a	3 85	8.33	6 00
Hydrocotyle sp. b	3 85	0 00	2 00
Juncus spp.	0 00	4 17	2 00
Lepidosperma elatius	3 85	0 00	2.00
Oxalis spp	3 85	0 00	2 00
Poa spp	7 69	4 17	6.00
Pterostylis spp	0 00	4 17	2.00
Senecio spp	0 00	12 50	6.00
Stellaria pungens	0 00	4 17	2.00
Urtica incisa	0 00	4 17	2.00
Ground fern			
Blechnum nudum	15 38	8 33	12 00
Blechnum wattsii	26.92	41 67	34 00

Bryophyte species	Logging	Wildfire	All sites
Isopterygium lmatum	42 31	25 00	34 00
Lembophyllium divulsum	26 92	33 33	30 00
Lopidium concinnum	73.08	50 00	62 00
Neckera pennata	19 23	0 00	10 00
Papillaria flavolimbata	3.85	8 33	6 00
*Plagiothecium lamprostachys (*Hampe) Jaeg	65 38	29 17	48 00
Ptychomnion aciculare	100 00	100.00	100 00
Pyrrhobryum mnioides	23 08	12 50	18 00
Pyrrhobryum parramattense	0 00	4 17	2 00
Racopilum cuspidigerum (Schwagr) Åongstr var *convolutaceum* (Mull Hal) Zant & Dijk.	42 31	41 67	42.00
Rhaphidorrhynchium amoenum	100 00	95 83	98 00
Rhynchostegium tenuifolium	11 54	0 00	6 00
Sauloma tenella	11 54	4 17	8 00
Sematophyllum subhumile var. *contiguum* (Mitt) Tan, Schofield & Ramsay	19 23	12.50	16.00
Thamnobryum pumilum	11 54	0 00	6 00
Thuidium furfurosum	38 46	16.67	28 00
Thuidium sparsum	46 15	45 83	46 00
Trachyloma planifolium	11.54	4.17	8 00
Warburgiella leucocytus (Müll Hal) Tan, Schofield & Ramsay	92 31	83 33	88 00
Weymouthia cochlearifolia	38 46	25 00	32 00
Weymouthia mollis	30.77	20 83	26.00
Wijkia extenuata	84 62	100 00	92 00
Leafy liverwort			
Acrobolbus cinerascens	0 00	4 17	2 00
Acrobolbus concinnus	3 85	0 00	2 00
Acrochila biserialis	3 85	4.17	4.00
Acromastigum colensoanum	26.92	16 67	22 00
Adelanthus falcatus	0 00	8 33	4 00
Balantiopsis diplophylla	50 00	58 33	54 00
Bazzania involuta	100.00	100 00	100 00
Bazzania monilinervis	26.92	20.83	24 00
Brevianthus flavus	0 00	8 33	4 00
Cephaloziella exiliflora	7 69	20 83	14 00
Cephaloziella hirta	3 85	0 00	2 00
Chandonanthus squarrosus	3 85	8.33	6 00
Cheilolejeunea mimosa	3 85	4.17	4.00
Chiloscyphus bispinosus aff	0 00	4 17	2.00
Chiloscyphus echinellus	65 38	54 17	60 00
Chiloscyphus latifolius (L) Engel & Schust	19 23	20 83	20 00
Chiloscyphus leucophyllus	23 08	33 33	28 00
Chiloscyphus minor (Nees) Engel & Schust	0 00	4 17	2 00
Chiloscyphus multipennus aff.	0.00	4 17	2 00
Chiloscyphus muricatus	53 85	37.50	46 00
Chiloscyphus novaezeelandiae	3 85	0 00	2 00
Chiloscyphus pallidus	19 23	4 17	12 00
Chiloscyphus rupicolus (Steph) Engel & Schust	3 85	0 00	2 00
Chiloscyphus semiteres	73 08	79.17	76 00
Chiloscyphus subporosus	0 00	4.17	2 00
Chiloscyphus villosus	7 69	4 17	6 00
Cuspidatula monodon	19 23	29 17	24.00
Frullania aterrima	7 69	0.00	4 00
Frullania clavata	69 23	45 83	58 00
Frullania falciloba	42 31	45 83	44 00
Frullania pentapleura	0 00	4 17	2 00
Frullania proboscophora	34.62	20.83	28 00
Frullania rostrata	34.62	45.83	40 00
Gackstroemia weindorferi	50 00	91 67	70.00
Geocalyx caledonicus	3 85	8 33	6 00
Heteroscyphus billardieri	15.38	25 00	20.00
Heteroscyphus coalitus	100 00	87 50	94 00
Heteroscyphus conjugatus	7 69	12 50	10 00
Heteroscyphus decipiens	0 00	4 17	2 00
Heteroscyphus fissistipus	96.15	83.33	90 00
Heteroscyphus knightii	3.85	8.33	6 00
Heteroscyphus limosus	19 23	37.50	28 00
Heteroscyphus sinosus	3.85	16 67	10 00
Heteroscyphus sp a	3 85	0.00	2 00
Heteroscyphus triacanthus	3 85	4 17	4 00
Isotachis intortifolia	3 85	4 17	4 00
Jamesoniella tasmanica	11 54	8 33	10 00
Jungermannia inundata	3 85	0 00	2.00
Kurzia compacta (Steph) Grolle	30.77	62.50	46 00
Kurzia hippurioides	30.77	79 17	54 00
Kurzia hippurioides aff	65.38	62 50	64 00
Kurzia sexfida	0 00	4 17	2 00
Kurzia tenax	3 85	4.17	4 00
Lejeunea drummondii	65 38	54 17	60.00
Lejeunea primordialis	11 54	0 00	6 00
Lepicolea scolopendra	7 69	8 33	8 00

Vascular plants	Logging	Wildfire	All sites
Dicksonia antarctica	84 62	75 00	80 00
Histiopteris incisa	76 92	54 17	66 00
Polystichum proliferum	84 62	66 67	76 00
Pteridium esculentum	69 23	62 50	66.00
Rumohra adiantiformis	11.54	12.50	12 00
Sticherus spp	3 85	0 00	2.00
Sticherus tener	0 00	4 17	2.00
Epiphytic fern			
Asplenium bulbiferum	11 54	12 50	12 00
Asplenium flabellifolium	3 85	0.00	2 00
Ctenopteris heterophylla	7 69	8 33	8 00
Cystopteris tasmanica	0 00	4 17	2.00
Grammitis billardieri	42 31	37.50	40 00
Grammitis magellanica ssp *nothofageti*	7 69	8.33	8 00
Grammitis sp a	57 69	54 17	56 00
Grammitis pseudocilliatus	3 85	0 00	2 00
Hymenophyllum australe	7.69	20.83	14 00
Hymenophyllum cupressiforme	34 62	41 67	38 00
Hymenophyllum flabellatum	30 77	33 33	32 00
Hymenophyllum marginatum	3 85	0 00	2 00
Hymenophyllum peltatum	30 77	58.33	44 00
Hymenophyllum rarum	34 62	41 67	38 00
Hymenophyllum spp	15 38	8 33	12 00
Microsorum pustulatum	42.31	33 33	38 00
Polyphlebium venosum	7 69	8.33	8 00
Tmesipteris obliqua	3 85	16 67	10 00
Tmesipteris spp	11 54	12 50	12.00
Climbers			
Billardeira longifolia	0 00	8 33	4 00
Clematis aristata	11 54	12.50	12 00

Bryophyte species	Logging	Wildfire	All sites	Vascular plants	Logging	Wildfire	All sites
Lepidozia concinna	0 00	20.83	10.00				
Lepidozia glaucophylla	23 08	12 50	18 00				
Lepidozia laevifolia	57.69	75.00	66 00				
Lepidozia obtusiloba Steph	7 69	12.50	10.00				
Lepidozia procera	50 00	79 17	64.00				
Lepidozia ulothrix	100 00	100 00	100 00				
Leptophyllopsis laxus	7 69	4.17	6.00				
Marsupidium surculosum	15 38	33 33	24.00				
Plagiochila baileyana	11 54	4 17	8 00				
Plagiochila fasciculata	61 54	37 50	50 00				
Plagiochila fuscella	0 00	4 17	2.00				
Plagiochila incurvicolla	7.69	4 17	6.00				
Plagiochila retrospectans	11.54	33 33	22 00				
Plagiochila spp.	15 38	12.50	14 00				
Plagiochila strombifolia	30.77	54.17	42 00				
Psiloclada clandestina	3 85	4 17	4.00				
Radula buccinifera	65 38	58 33	62 00				
Radula compacta	23 08	41.67	32 00				
Radula multiamentula	3 85	8 33	6 00				
Radula ratkowskiana	3.85	8 33	6.00				
Radula retroflexa	3 85	0.00	2 00				
Radula tasmanica	0 00	4 17	2 00				
Saccogynidium decurvum	0 00	4 17	2.00				
Schistochila lehmanniana	46.15	45 83	46 00				
Schistochila pseudocilhata	3.85	0 00	2 00				
Telaranea centipes	3 85	8 33	6 00				
Telaranea mooreana	15 38	16 67	16.00				
Telaranea patentissima	88 46	95 83	92.00				
Telaranea tetradactyla	7.69	0 00	4 00				
Teleranea herzogii (Hodgs) Hodgs	3.85	16.67	10.00				
Temnoma townrowii	15.38	29 17	22 00				
Trichocolea mollissima	26 92	37 50	32.00				
Tylimanthus diversifolius Hodgs	30.77	33.33	32 00				
Tylimanthus pseudosaccatus	19 23	25 00	22.00				
Tylimanthus tenellus	30 77	16 67	24.00				
Zoopsis argentea	96 15	83 33	90 00				
Zoopsis leitgebiana	26 92	54 17	40 00				
Thallose liverwort							
Aneura alterniloba	3 85	4 17	4.00				
Hymenophyton flabellatum	26 92	29 17	28 00				
Metzgeria decipiens	88 46	83.33	86 00				
Metzgeria saccata	15 38	8 33	12 00				
Metzgeria spp	0 00	8.33	4 00				
Pallaviciniaceae	7 69	20 83	14.00				
Podomitrium phyllanthus	46 15	33 33	40 00				
Riccardia aequicellularis	30 77	33 33	32 00				
Riccardia cochleata	50.00	66 67	58 00				
Riccardia colensoi	0 00	4.17	2.00				
Riccardia crassa	53 85	66 67	60 00				
Riccardia eriocaula	0 00	4 17	2.00				
Riccardia spp	11 54	50.00	30 00				
Riccardia wattsiana	7 69	4 17	6 00				
Symphyogyna podophylla	53.85	29.17	42 00				
Treubia tasmanica	0 00	16 67	8 00				

BIBLIOGRAPHY

Andersson LI, Hytteborn H (1991) Bryophytes and decaying wood - comparison between managed and natural forest. *Holoarctic Ecology* **14**, 121-130.

Ashton DH (1981a) The ecology of the boundary between *Eucalyptus regnans* F. Muell and *E. obliqua* L'Herit. in Victoria. *Proceedings of the Ecological Society of Australia* **11**, 75-94.

Ashton DH (1981b) Fire in Tall Open Forests. In 'Fire and the Australian Biota'. (Eds AM Gill, RH Groves and IR Noble). (Australian Academy of Science: Canberra)

Ashton DH (1986) Ecology of bryophytic communities in mature *Eucalyptus regnans* F.Muell. forest at Wallaby Creek, Victoria. *Australian Journal of Botany* **34**, 107-129.

Ashton DH, Attiwill PM (1994) Tall open forests. In 'Australian Vegetation'. (Ed. RH Groves) pp. 157-196. (Cambridge University Press: Cambridge)

Ashton DH, McCrae R (1970) Distribution of epiphytes on Beech Forest (*Nothofgus cunninghamii*) trees at Mt Donna Buang Vic. *The Victorian Naturalist* **87**, 253-261.

Attiwill PM (1994a) The disturbance of forest ecosystems - the ecological basis for conservative management. *Forest Ecology and Management* **63**, 247-300.

Attiwill PM (1994b) Ecological disturbance and the conservative management of eucalypt forests in Australia. *Forest Ecology and Management* **63**, 301-346.

Baker SC (2000) Forest litter beetles and their habitat: a comparison of forest regeneration by wildfire and logging practices. Honours Thesis, University of Tasmania.

Barker MJ (1991) 'The effect of fire on west coast lowland rainforest. Tasmanian NRCP Technical Report.' Forestry Commission Tasmania, and Department of the Arts, Sport, the Environment and Tourism and Territories, No7, Canberra.

Bashford D, Taylor R, Driessen M, Doran N, Richardson A (2001) Research on invertebrate assemblages at the Warra LTER site. *Tasforests* **13**, 109-118.

Bassett OD, Edwards LG, Plumpton BS (2000) A comparison of four-year-old regeneration following six silvicultural treatments in a wet eucalypt forest in southern Tasmania. *Tasforests* **12**, 35-53.

Bates JW (1992) Influence of chemical and physical factors on *Quercus* and *Fraxinus* epiphytes at Loch Sunart, Western Scotland - a multivariate-analysis. *Journal of Ecology* **80**, 163-179.

Bauhus J (1999) Silvicultural practices in Australian native forests - an introduction. *Australian Forestry* **62**, 217-222.

Beadle NCW, Costin AB (1952) Ecological classification and nomenclature. *Proceedings of the Linnean Society New South Wales* **77**, 61-82.

Beever JE (1984) Moss epiphytes of tree-ferns in a warm-temperate forest, New Zealand. *Journal of the Hattori Botanical Laboratory* **56**, 89-95.

Belbin L (1991a) 'PATN: Pattern Analysis Package. Technical reference manual.' (CSIRO. Division of Wildlife Ecology: Canberra)

Belbin L (1991b) 'PATN: Pattern Analysis Package. Users Guide.' (CSIRO. Division of Wildlife Ecology: Canberra)

Billings WD, Drew WB (1938) Bark factors affecting the distribution of corticolous bryophytic communities. *American Midland Naturalist* **20**, 302-330.

Blanks PAM (1996) The predictive value of Ecological Vegetation Classes for the presence of bryophytes. Honours Thesis, University of Melbourne.

Boudreault C, Gauthier S, Bergeron Y (2000) Epiphytic lichens and bryophytes on *Populus tremuloides* along a chronosequence in the southwestern boreal forest of Quebec, Canada. *Bryologist* **103**, 725-738.

Bradfield GE, Scagel A (1984) Correlations among vegetation strata and environmental variables in subalpine spruce-fir forests, south-eastern British Columbia. *Vegetatio* **55**, 105-114.

Brasell HM, Davies SK, Mattay JP (1986) Nitrogen fixation associated with bryophytes colonising burnt sites in Southern Tasmania, Australia. *Journal of Bryology* **14**, 134-149.

Brasell HM, Mattay JP (1984) Colonisation by bryophytes of burned *Eucalyptus* forest in Tasmania, Australia: Changes in biomass and element content. *The Bryologist* **87**, 302-307.

Bray RT, Curtis JT (1957) An ordination of the upland forest communities of southern Wisconsin. *Ecological Monographs* **27**, 325-349.

Brown MJ (1996) Benign neglect and active management in Tasmanias forests - a dynamic balance or ecological collapse. *Forest Ecology and Management* **85**, 279-289.

Brown MJ, Elliot HJ, Hickey JE (2001) An overview of the Warra Long-Term Ecological Research Site. *Tasforests* **13**, 1-8.

Brown MJ, Hickey JE (1990) Tasmanian forest - genes or wilderness. *Search* **21**, 86-87.

Brown MJ, Jarman SJ, Kantvilas G (1994) Conservation and reservation of non-vascular plants in Tasmania, with special reference to lichens. *Biodiversity and Conservation* **3**, 263-278.

Buchanan AM (Ed.) (1999) 'A census of the vascular plants of Tasmania and index to the students flora of Tasmania.' (The Tasmanian Herbarium: Hobart)

Buck WR, Vitt DH, Malcolm WM (2002) 'Key to the genera of Australian mosses. Flora of Australia Supplementary Series No 14.' (Australian Biological Resources Study: Canberra)

Burgman MA (1996) Characterisation and delineation of the eucalypt old-growth forest estate in Australia: a review. *Forest Ecology and Management* **83**, 149-161.

Carleton TJ, MacLellan P (1994) Woody vegetation responses to fire versus clear-cutting logging: A comparitive survey in the central Canadian boreal forest. *Ecoscience* **1**, 141-152.

Centre for Resource and Environmental Studies (1999) ANUCLIM version 5.0. In. (The Australian National University: Canberra)

Chesterfield E (1996) 'Changes in mixed forest after fire and after clearfelling silviculture on the Errinundra Plateau.' Department of Natural Resources and Environment., No 142., Melbourne.

Clarke KR (1993) Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* **18**, 117-143.

Clements FE (1916) 'Plant succession, an anlaysis of the development of vegetation.' (Carnegie Institute of Washington: Washington)

Commonwealth of Australia and the State of Tasmania (1996) 'Tasmanian Regional Forest Agreement (RFA) information kit.' (Commonwealth of Australia and State of Tasmania: Hobart)

Connell JH, Slatyer RO (1977) Mechanisms of succession in natural communities and their role in community stability and organisation. *American Naturalist* **111**, 1119-1144.

Cook IO, Drinnan AN (1984) 'Successional trends in vegetation following eucalypt harvesting in mature mixed forest on the Errinundra Plateau, East Gippsland.' Forestry Commission of Victoria., 259.

Cooper-Ellis S (1998) Bryophytes in old-growth forests of Western Massachusetts. *Journal of the Torrey Botanical Society* **125**, 117-132.

Cremer KW, Mount AB (1965) Early stages of plant succession following the complete felling and burning of *Eucalyptus regnans* forest in the Florentine Valley, Tasmania. *Australian Journal of Botany* **13**, 303-322.

Crites S, Dale MRT (1998) Diversity and abundance of bryophytes, lichens, and fungi in relation to woody substrate and successional stage in aspen mixedwood boreal forests. *Canadian Journal of Botany* **76**, 641-651.

Crum HA (2001) 'Structural Diversity of Bryophytes.' (University of Michigan: Michigan)

Cunningham TM, Cremer KW (1965) Control of the understory in wet eucalypt forests. *Australian Forestry* **29**, 4-14.

Dalton PJ, Kantvilas G, Mills AK (1999) Non vascular plants. In 'Vegetation of Tasmania'. (Eds JB Reid, RS Hill, MJ Brown and MJ Hovendon) pp. 125-144. (Australian Government Printing Service: Canberra)

Dalton PJ, Seppelt RD, Buchanan AM (1991) An annotated checklist of Tasmanian mosses. In 'Aspects of Tasmanian Botany - a tribute to Winifred Curtis.' (Ed. MR Banks) pp. 15-32. (Royal Society of Tasmania: Hobart.)

Duncan BD, Isaac G (1986) 'Ferns and allied plants of Victoria, Tasmania and South Australia.' (Melbourne University Press: Melbourne)

Duncan D, Dalton PJ (1982) Recolonisation by bryophytes following fire. *Journal of Bryology* **12**, 53-63.

During HJ, van Tooren BF (1990) Bryophyte interactions with other plants. *Botanical Journal of the Linnean Society* **104**, 79-98.

Dyne G (1991) 'Attributes of old growth forest in Australia: proceedings of a workshop sponsored by the National Forest Inventory.' Bureau of Rural Resources, Department of Primary Industries and Energy, WP/4/92, Canberra.

Egler FE (1954) Vegetation science concepts. I. Initial floristic composition - a factor in old-field vegetation development. *Vegetatio* **4**, 412-417.

Faith DP, Minchin PR, Belbin L (1987) Compositional dissimilarity as a robust measure of ecological distance. *Vegetatio* **69**, 57-68.

Faith DP, Walker PA (1996) Environmental diversity: On the best-possible use of surrogate data for assessing the relative biodiversity of sets of areas. *Biodiversity and Conservation* **5**, 399-415.

Fensham RJ, Streimann H (1997) Broad landscape relations of the moss flora from inland dry rainforest in north Queensland, Australia. *Bryologist* **100**, 56-64.

Florence RG (1996) 'Ecology and silviculture of eucalypt forests.' (CSIRO: Collingwood, Victoria)

Forest Practices Board (2000) 'Forest practices code.' (Forest Practices Board: Hobart)

Forestry Tasmania (1998) 'Lowland wet eucalypt forests. Native Forest Silviculture Technical Bulletin No. 8.' Forestry Tasmania, Hobart.

Forestry Tasmania (2002) 'Forestry Tasmania sustainable forest management report. 2001/2002.' Forestry Tasmania, Hobart.

Foster DR (1985) Vegetation development following fire in *Picea mariana* (Black Spruce) - *Pleurozium* forests of south-eastern Labrador, Canada. *Journal of Ecology* **73**, 517-534.

Franklin JF (1990) Biological legacies: a critical management concept from Mount St Helens. In 'Transactions of the 55th North American Wildlife Natural Resources Conference' pp. 216-219)

Franklin JF (1993) Lessons from old growth. *Journal of Forestry* **91**, 10-13.

Franklin JF, Berg DR, Thornburgh DA, Tappeiner JC (1997) Alternative silvicultural approaches to timber harvesting: variable retention harvest systems. In 'Creating a forestry for the 21st century: The science of ecosystem management'. (Eds KA Kohm and JF Franklin) pp. 111-139. (Island Press: Washington D.C.)

Franklin JF, Cromack JK, Denison W, Mc Kee A, Maser C, Sedell J, Swanson F, Juday G (1981) 'Ecological attributes of old-growth Douglas-fir forests.' (USDA Forest Service General Technical Report PNW-118. Pacific North-west Forest and Range Experimental Station, Portland, OR.)

Frisvoll AA, Presto T (1997) Spruce forest bryophytes in central Norway and their relationship to environmental factors including modern forestry. *Ecography* **20**, 3-18.

Gilbert JM (1959) Forest succession in the Florentine Valley, Tasmania. *Papers and proceedings of the Royal Society of Tasmania.* **93**, 129-151.

Gilbert JM, Cunningham TM (1972) Regeneration of harvested forests. I. State forests in Tasmania. *Appita* **26**, 43-45.

Gill AM (1997) Eucalypts and fires: interdependant or independant? In 'Eucalypt Ecology'. (Eds JE Williams and JCZ Woinarski) pp. 151-167. (Cambridge University Press: Cambridge)

Glaser PH, Janssens JA, Siegel DI (1990) The response of vegetation to chemical and hydrological gradients in the Lost River Peatland, Northern Minnesota. *Journal of Ecology* **78**, 1021-1048.

Gould WA, Walker MD (1999) Plant communities and landscape diversity along a Canadian arctic river. *Journal of Vegetation Science* **10**, 537-548.

Gradstein SR, Van Reenen GBA, D. G (1989) Species richness and origin of the bryophyte flora of the Colombian Andes. *Acta Botanica Neerlandica* **38**, 439-448.

Gustafsson L, Eriksson I (1995) Factors of importance for the epiphytic vegetation of *Aspen Populus Tremula* with special emphasis on bark chemistry and soil chemistry. *Journal of Applied Ecology* **32**, 412-424.

Gustafsson L, Hallingback T (1988) Bryophyte flora and vegetation of managed and virgin coniferous forest in south west Sweden. *Biological Conservation* **44**, 283-300.

Halpern CB, Spies TA (1995) Plant species diversity in natural and managed forests of the Pacific Northwest. *Ecological Applications* **5**, 913 - 934.

Hansen AJ, Spies TA, Swanson FJ, Ohmann JL (1991) Conserving biodiversity in managed forests. *BioScience* **41**, 382-392.

Hazell P, Gustafsson L (1999) Retention of trees at final harvest - evaluation of a conservation technique using epiphytic bryophyte and lichen transplants. *Biological Conservation* **90**, 133-142.

Heinselman ML (1981) Fire and succession in the conifer forests of northern North America. In 'Forest succession: concepts and applications'. (Eds DC West, HH Shugart and DB Botkin) pp. 374-405. (Springer-Verlag: Berlin)

Hickey JE (1982) Natural and artificial regeneration of some Tasmanian rainforest trees. In 'Tasmanian rainforests: recent research results'. (Ed. FER Fund). (Forestry Commission: Hobart)

Hickey JE (1993) A comparison of old growth mixed forest with regeneration resulting from logging or wildfire. MSc. Thesis, University of Tasmania.

Hickey JE (1994) A floristic comparison of vascular species in Tasmanian oldgrowth mixed forest with regeneration resulting from logging and wildfire. *Australian Journal of Botany* **42**, 383-404.

Hickey JE, Blakesley AJ, Turner B (1982) Seedfall and germination of *Nothofagus cunninghamii* (Hook.) Oerst., *Eucryphia lucida* (Labill.) Baill. and *Atherosperma moschatum* Labill. Implications for regeneration practice. *Australian Forest Research* **13**, 21-28.

Hickey JE, Neyland MG, Bassett OD (2001) Rationale and design for the Warra silvicultural systems trial in wet *Eucalyptus obliqua* forests in Tasmania. *Tasforests* **13**, 155-182.

Hickey JE, Savva M (1992) 'The extent, regeneration and growth of Tasmanian lowland mixed forest.' (Forestry Commission, Tasmania: Hobart)

Hill RS, Read J (1984) Post fire regeneration of rainforest and mixed forest in Western Tasmania. *Australian Journal of Botany* **32**, 481-493.

Howard TM, Ashton DH (1973) The distribution of *Nothofagus cunninghamii* Oerst. rainforest. *Proceedings of the Royal Society of Victoria* **86**, 47-75.

Ingerpuu N, Vellak K, Kukk T, Partel M (2001) Bryophyte and vascular plant species richness in boreo-nemoral moist forests and mires. *Biodiversity and Conservation* **10**, 2153-2166.

Jackson ML (1958) 'Soil chemical analyses.' (Prentice Hall: New Jersey)

Jackson WD (1968) Fire, air, water and earth - an elemental ecology of Tasmania. *Proceedings of the Ecological Society of Australia* **3**, 9-16.

Jackson WD (1999) Vegetation types. In 'Vegetation in Tasmania'. (Eds JB Reid, RS Hill, MJ Brown and MJ Hovendon) pp. 1-10. (Australian Government Printing Service: Canberra)

Jarman SJ, Fuhrer BA (1995) 'Mosses and liverworts of rainforest in Tasmania and South-eastern Australia.' (CSIRO Australia and Forestry Tasmania: Melbourne)

Jarman SJ, Kantvilas G (1994) Lichens and bryophytes of the Tasmanian World Heritage Area. II. Three forest sites at Pelion Plains. *Tasforests* **6**, 103-120.

Jarman SJ, Kantvilas G (1995a) Epiphytes on an old Huon pine tree (*Lagarostrobos franklinii*) in Tasmanian rainforest. *New Zealand Journal of Botany* **33**, 65-78.

Jarman SJ, Kantvilas G (1995b) 'A floristic study of rainforest bryophytes and lichens in Tasmania's Myrtle-beech alliance.' (Forestry Tasmania and Department of the Environment, Sport and Territories, Canberra, Hobart).

Jarman SJ, Kantvilas G (1997) 'Impacts on forestry operations on cryptogams in Tasmania's eucalypt forests.' (Forestry Tasmania and Commonwealth Department of Primary Industries and Energy: Hobart)

Jarman SJ, Kantvilas G (2001a) Bryophytes and lichens at the Warra LTER site. I. An inventory of species in *Eucalyptus obliqua* wet sclerophyll forest. *Tasforests* **13**, 193-216.

Jarman SJ, Kantvilas G (2001b) Bryophytes and lichens at the Warra LTER site. II. Understorey habitats in *Eucalyptus obliqua* wet sclerophyll forest. *Tasforests* **13**, 217-237.

Jarman SJ, Kantvilas G, Brown MJ (1991) 'Floristic and ecological studies in Tasmanian rainforest.' (Forestry Commission, Tasmania and Department of the Arts, Sport and Environment, Tourism and Territories: Canberra)

Johnston MH, Elliot JA (1996) Impacts of logging and wildfire on an upland black spruce community in northwestern Ontario. *Environmental Monitoring and Assessment* **39**, 283-297.

Jonsson BG, Esseen PA (1990) Treefall disturbance maintains high bryophyte diversity in a boreal spruce forest. *Journal of Ecology* **78**, 924-36.

Jonsson BG, Esseen PA (1998) Plant colonisation in small forest-floor patches - importance of plant group and disturbance traits. *Ecography* **21**, 518-526.

Kantvilas G, Jarman SJ (1993) The cryptogamic flora of an isolated rainforest fragment in Tasmania. *Botanical Journal of the Linnean Society* **111**, 211-228.

Kantvilas G, Minchin PR (1989) An analysis of epiphytic lichen communities in Tasmanian cool temperate rainforest. *Vegetatio* **84**, 99-112.

Kenkel NC, Orlóci L (1986) Applying metric and nonmetric multidimensional scaling to ecological studies: some new results. *Ecology* **67**, 919-928.

Kent K, Coker P (1996) 'Vegetation description and analysis. A practical approach.' (CRC Press: London)

Kessler M (2001) Pteridophyte species richness in Andean forests in Bolivia. *Biodiversity and Conservation* **10**, 1473-1495.

Kirkpatrick JB (1997) Vascular plant-eucalypt interactions. In 'Eucalypt Ecology. Individuals to ecosystems'. (Eds JE Williams and JCZ Woinarski) pp. 227-245. (Cambridge University Press: Cambridge)

Kirkpatrick JB, Peacock RJ, Cullen PJ, Neyland MJ (1988) 'The wet eucalypt forests of Tasmania.' (Tasmanian Conservation Trust Inc.: Hobart.)

Korven-Korpinen E, White MG (1972) Regeneration of harvested forests in Tasmania. II. Forestry practices at ANM Ltd. *Appita* **26**, 45-46.

Kruys N, Fries C, Jonsson BG, Lamas T, Stal G (1999) Wood-inhabiting cryptogams on dead Norway spruce (Picea abies) trees in managed Swedish boreal forests. *Canadian Journal of Forest Research* **29**, 178-186.

Kruys N, Jonsson BG (1999) Fine woody debris is important for species richness on logs in managed boreal spruce forests of northern Sweden. *Canadian Journal of Forest Research* **29**, 1295-1299.

La Roi GH, Stringer MHL (1976) Ecological studies in the boreal spruce-fir forests of the North American Taiga. II. Analysis of the bryophyte flora. *Canadian Journal of Botany* **54**, 619-643.

Lee TD, La Roi GH (1979a) Bryophyte understorey vascular plant beta diversity in relation to moisture and elevation gradients. *Vegetatio* **40**, 29-38.

Lee TD, La Roi GH (1979b) Gradient analysis of bryophytes in Jasper National Park, Alberta. *Canadian Journal of Botany* **57**, 914-925.

Lesica P, McCune B, Cooper SV, Hong WS (1991) Differences in lichen and bryophyte communities between old growth and managed second growth forests in the Swan Valley, Montana. *Canadian Journal of Botany* **69**, 1745-1755.

Lindenmayer DB (1995) Forest disturbance, forest wildlife conservation and the conservative basis for forest management in the Mountain Ash forests of Victoria - Comment. *Forest Ecology and Management* **74**, 223-231.

Lindenmayer DB (2002) The ecological roles of logs in Australian forests and the potential impacts of harvesting intensification on log-using biota. *Pacific Conservation Biology* **8**, 121-140.

Lindenmayer DB, Cunningham RB, Donnelly CF, Franklin JF (2000) Structural features of old-growth Australian montane ash forests. *Forest Ecology and Management* **134**, 189-204.

Lindenmayer DB, Cunningham RB, Nix HA, Tanton MT, Smith AP (1991) Predicting the abundance of hollow-bearing trees in montane forests of southeastern Australia. *Australian Journal of Ecology* **16**, 91-98.

Lindenmayer DB, Cunningham RB, Tanton MT, Smith AP, Nix HA (1990a) The conservation of arboreal marsupials in the montane ash forests of the Central Highlands of Victoria. I. Factors affecting the occupancy of trees with hollows. *Biological Conservation* **54**, 111-131.

Lindenmayer DB, Franklin JF (1997) Managing stand structure as part of ecologically sustainable forest management in Australian mountain ash forests. *Conservation Biology* **11**, 1053-1068.

Lindenmayer DB, Incoll RD, Cunningham RB, Donnelly CF (1999) Attributes of logs on the floor of Australian Mountain Ash (*Eucalyptus regnans*) forests of different ages. *Forest Ecology and Management* **123**, 195-203.

Lindenmayer DB, McCarthy MA (2002) Congruence between natural and human forest disturbance: a case study from Australian montane ash forests. *Forest Ecology and Management* **155**, 319-335.

Lindenmayer DB, Norton TW, Tanton MT (1990b) Differences between wildfire and clearfelling on the structure of montane ash forests of Victoria and their implications for fauna dependent on tree hollows. *Australian Forestry* **53**, 61-68.

Linder P, Elfving B, Zackrisson O (1997) Stand structure and successional trends in virgin boreal forest reserves in Sweden. *Forest Ecology and Management* **98**, 17-33.

Longton RE (1992) The role of bryophytes and lichens in terrestrial ecosystems. In 'Bryophytes and lichens in a changing environment'. (Eds JW Bates and AM Farmer). (Clarendon Press: Oxford)

Luke RH, McArthur AG (1978) 'Bushfires in Australia.' (Australian Government Publishing Service: Canberra)

McAlister S (1997) Cryptogam communities on fallen logs in the Duke Forest, North Carolina. *Journal of Vegetation Science* **8**, 115-124.

McCuaig A (1982) The status of rainforest in Tasmania: A study of settlement, forest industrialisation, and land management in relation to rainforest disturibution and future prospects. In 'The Tasmanian Rainforest Estate. Environmental Studies Occassional Paper 15.' (Ed. R Jones). (University of Tasmania: Hobart)

McCullagh P, Nelder JA (1989) 'Generalised linear models.' (Chapman and Hall: London)

McCune B, Antos JA (1981) Diversity relationships of forest layers in the Swan Valley, Montana. *Bulletin of the Torrey Botanical Club* **108**, 354-361.

McCune B, Mefford MJ (1999) 'PC-ORD, Multivariate Analysis of Ecological Data.' (MjM Software: Oregon)

McKenny HJA, Kirkpatrick JB (1999) The role of fallen logs in the regeneration of tree species in Tasmanian mixed forest. *Australian Journal of Botany* **47**, 745-753.

McMullan-Fisher SJM, May TW, Keane PJ (2002) The macrofungal community and fire in a Mountain Ash forest in southern Australia. *Fungal Diversity* **10**, 57-76.

Meggs J (1997) 'Logs in a state of decay.' Forestry Tasmania, Research Note No2, Hobart.

Mendel LC, Kirkpatrick JB (2002) Historical progress of biodiversity conservation in the protected-area system of Tasmania. *Conservation Biology* **16**, 1520-1529.

Michaels KF (1999) Effects of clearfell harvesting on lucanid beetles (Coleoptera: Lucanidae) in wet and dry sclerophyll forests in Tasmania. *Journal of Insect Conservation* **3**, 85-95.

Milne J, Louwhoff S (1999) Vertical distribution of bryophytes and lichens on a Myrtle Beech, *Nothofagus cunninghamii* (Hook.) Oerst. *Hikobia* **13**, 23-30.

Minchin PR (1987) An evaluation of the relative robustness of techniques for ecological ordination. *Vegetatio* **69**, 89-107.

Minchin PR (1990) 'DECODA users manual.' (Research School of Pacific Studies. Australian National University.: Canberra)

Minitab release 13.1 (2000) Minitab Statsitical Software Inc. In.

Moscal A, Askey-Doran M, Kirkpatrick JB, Lambourne MJ, Dalton PJ, Seppelt RD (1997) 'A preliminary assessment of the conservation and reservation status of Tasmanian bryophytes.' (Environment and Heritage Technical Committee: Hobart)

Moscal A, Kirkpatrick JB (1995) 'The reservation status of Tasmanian hepatic and bryophyte species.' Tasmanian Conservation Trust, Report 2, Hobart.

Moscal A, Kirkpatrick JB (1997) 'Atlas of the bryophytes of Tasmania. University of Tasmania.' (Tasmanian Conservation Trust: Hobart)

Mount AB (1969) Eucalypt ecology as related to fire. *Tall Timbers Fire Ecology Conference Proceedings* **9**, 75-108.

Mount AB (1979) Natural regeneration processes in Tasmanian forests. *Search* **10**, 180-186.

Mueck SG, Peacock RJ (1992) 'Impacts of intensive timber harvesting on the forests of East Gippsland, Victoria.' (Flora and Fauna Branch, Department of Conservation and Natural Resources: Melbourne)

Mueller-Dombois D, Ellenberg H (1974) 'Aims and methods of vegetation ecology.' (Wiley: New York.)

Muhle H, LeBlanc F (1975) Bryophyte and lichen succession on decaying logs. I. Analysis along an evaporation gradient in eastern Canada. *Journal of the Hattori Botanical Laboratory* **39**, 1-33.

Nguyen-Xuan T, Bergeron Y, Simard D, Fyles JW, Pare D (2000) The importance of forest floor disturbance in the early regeneration patterns of the boreal forest of western and central Quebec: a wildfire versus logging comparison. *Canadian Journal of Forest Research* **30**, 1353-1364.

Nicholson E (1999) Winds of change for silvicultural practice in NSW native forests. *Australian Forestry* **62**, 7-18.

Nix HA (1986) A biogeographic analysis of Australian elapid snakes. In 'Atlas of Elapid snakes of Australia'. (Ed. R Longmore.) pp. 4-15. (AGPS: Canberra.)

Noble IR, Slatyer RO (1980) The use of vital attributes to predict successional changes in plant communities subject to recurrent distrubances. *Vegetatio* **43**, 5-21.

Norton TW (1996) Conserving biological diversity in Australias temperate eucalypt forests. *Forest Ecology and Management* **85**, 21-33.

Ohlson M, Söderström L, Hornberg G, Zackrisson O, Hermansson J (1997) Habitat qualities versus long-term continuity as determinants of biodiversity in boreal old-growth swamp forests. *Biological Conservation* **81**, 221-231.

Økland RH, Eilertsen O (1994) Canonical correspondance analysis with variation partitioning: some comments and an application. *Journal of Vegetation Science* **5**, 117-126.

Ough K (2001) Regeneration of wet forest flora a decade after clear-felling or wildfire—is there a difference? *Australian Journal of Botany* **49**, 645-664.

Ough K, Murphy A (1996) The effect of clearfell logging on tree ferns in Victorian wet forest. *Australian Forestry* **59**, 178-188.

Ough K, Murphy A (1998) 'Understorey islands: a method of protecting understorey flora during clearfelling operations. VSP Internal Report No. 29.' (Department of Natural Resources and Environment, Victoria: Melbourne)

Ough K, Ross J (1992) 'Floristics, fire and clearfelling in wet forests of the Central Highlands, Victoria.' Department of Conservation and Environment, No 11., Melbourne.

Packham JM, May TW, Brown MJ, Wardlaw TJ, Mills AK (2002) Macrofungal diversity and community ecology in mature and regrowth wet eucalypt forest in Tasmania: A multivariate study. *Austral Ecology* **27**, 149-161.

Palmer MW (1986) Pattern in corticolous bryophyte communities of the North Carolina Piedmont: do mosses see the forest or the trees? *The Bryologist* **89**, 59-65.

Peck JE (1997) Commercial moss harvest in northwestern Oregon: Describing the epiphyte communities. *Northwest Science* **71**, 186-195.

Pharo EJ, Beattie AJ (1997) Bryophyte and lichen diversity - a comparative study. *Australian Journal of Ecology* **22**, 151-162.

Pharo EJ, Beattie AJ (2001) Management forest types as a surrogate for vascular plant, bryophyte and lichen diversity. *Australian Journal of Botany* **49**, 23-30.

Pharo EJ, Beattie AJ (2002) The association between substrate variability and bryophyte and lichen diversity in eastern Australian forests. *Bryologist* **105**, 11-26.

Pharo EJ, Beattie AJ, Binns D (1999) Vascular plant diversity as a surrogate for bryophyte and lichen diversity. *Conservation Biology* **13**, 282-292.

Pharo EJ, Blanks PAM (2000) Managing a neglected component of biodiversity: a study of bryophyte diversity in production forests of Tasmania's north-east. *Australian Forestry* **63**, 128-135.

Pharo EJ, Vitt DH (2000) Local variation in bryophyte and macro-lichen cover and diversity in montane forests of Western Canada. *The Bryologist* **103**, 455-466.

Pike LH, Denison WC, Tracey DM, Sherwood MA, Rhoades FM (1975) Floristic survey of epiphytic lichens and bryophytes growing on old-growth conifers in western Oregon. *The Bryologist* **78**, 289-402.

Prendergast JR, Quinn RM, Lawton JH, Eversham BC, Gibbons DW (1993) Rare species, the coincidence of diversity hotspots and conservation strategies. *Nature* **365**, 335-337.

Qian H, Klinka K, Song XH (1999) Cryptogams on decaying wood in old-growth forests of southern coastal British Columbia. *Journal of Vegetation Science* **10**, 883-894.

Quinby PA (2000) First-year impacts of shelterwood logging on understory vegetation in an old-growth pine stand in central Ontario, Canada. *Environmental Conservation* **27**, 229-241.

Rambo TR (2001) Decaying logs and habitat heterogeneity: implications for bryophyte diversity in western Oregon forests. *Northwest Science* **75**, 270-279.

Rambo TR, Muir PS (1998a) Bryophyte species associations with coarse woody debris and stand ages in Oregon. *Bryologist* **101**, 366-376.

Rambo TR, Muir PS (1998b) Forest floor bryophytes of *Pseudotsuga menziesii, Tsuga heterophylla* stands in Oregon: influences of substrate and overstory. *Bryologist* **101**, 116-130.

Ratkowsky DA (1987) Check-list of the Tasmanian liverworts. *Papers and Proceedings of the Royal Society of Tasmania* **121**, 153-158.

Ratkowsky DA, Ratkowsky AV (1982) The bryophytes of the Mt Wellington Range, Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* **116**, 97-115.

Read J (1999) Rainforest ecology. In 'Vegetation of Tasmania'. (Eds JB Reid, RS Hill, MJ Brown and MJ Hovendon) pp. 161-197. (Australian Government Printing Service: Canberra)

Reich PB, Bakken P, Carlson D, Frelich LE, Friedman SK, Grigal DF (2001) Influence of logging, fire, and forest type on biodiversity and productivity in southern boreal forests. *Ecology* **82**, 2731-2748.

Resource Assessment Commission (1992) 'Forest timber inquiry. Final report. Overview.' (Australian Government Publishing Service: Canberra)

Resource Planning and Development Commission (2002) 'Sustainability indicators for Tasmanian forests. 1996 - 2001. Version 25. 2.02.' (Tasmanian and Commonwealth Governments: Hobart)

Rey Benayas JMR (1995) Patterns of diversity in the strata of boreal montane forest in British-Columbia. *Journal of Vegetation Science* **6**, 95-98.

Roberts MR, Gilliam FS (1995) Patterns and machanisms of plant diversity in forested ecosystems: implications for forest management. *Ecological Applications* **5**, 969-977.

Roberts N (2002) Tree-ferns as a substrate for bryophytes and ferns in south-eastern Tasmania. Hons. Thesis, University of Tasmania.

Ross-Davis AL, Frego KA (2002) Comparison of plantations and naturally regenerated clearcuts in the Acadian Forest: forest floor bryophyte community and habitat features. *Canadian Journal of Botany* **80**, 21-33.

Schmitt CK, Slack NG (1990) Host specificity of epiphytic lichens and bryophytes: a comparison of the Adirondack Mountains (New York) and the Southern Blue Ridge Mountains (North Carolina). *The Bryologist* **93**, 257-274.

Scott GAM (1970) Vegetation studies on Secretary Island, Fiorland. *New Zealand Journal of Botany* **8**, 30-50.

Scott GAM (1985) 'Southern Australian Liverworts.' (Australian Government Publishing Service.: Canberra.)

Scott GAM (1994) Elementary reflections on the biology of bryophytes. *The Victorian Naturalist* **111**, 112-115.

Scott GAM, Bradshaw JA (1986) Australian liverworts (Hepaticae): Annotated list of binomials and check-list of published species with bibliography. *Brunonia* **8**, 1-171.

Scott GAM, Entwisle TJ, May TW (1997) 'A conservation overview of Australian non-marine lichens, bryophytes, algae and fungi.' (Environment Australia: Canberra)

Scott GAM, Rawley JA (1975) A lowland vegetation sequence in South Westland: Pakini bogs to mixed Beech - Podocarp forest 2. *Proceedings of the New Zealand Ecological Society* **22**, 93-108.

Scott GAM, Stone IG, Rosser C (1976) 'The mosses of South-eastern Australia.' (Academic Press.: London.)

Scotts DJ (1991) Old growth forests: their ecological characteristics and value to forest-dependant vertebrate fauna of south-east Australia. In 'Conservation of Australia's forest fauna'. (Ed. D Lunney). (Surrey Beatty and Sons, Pty Ltd,: Mosman)

Shea SR, Peet GB, Cheney NP (1993) The role of fire in forest management. In 'Fire in the Australian biota'. (Eds AM Gill, RH Groves and IR Noble) pp. 443 - 470. (Australian Academy of Science: Canberra)

Slack NG (1976) Host specificity of bryophytic epiphytes in eastern north America. *Journal of the Hattori Botanical Laboratory* **41**, 107-132.

Slack NG (1977) Species diversity and community structure in bryophytes: New York State studies. *Bulletin of the New York State Museum* **428**, 1-70.

Smith AJE (1982) 'Bryophyte ecology.' (Chapman and Hall.: New York.)

Söderström L (1981) Distribution of bryophytes in spruce forests on hill slopes in central Sweden. *Wahlenbergia* **7**, 141-153.

Söderström L (1988a) The occurrence of epixylic bryophyte and lichen species in an old natural and a managed forest stand in northeast Sweden. *Biological Conservation* **45**, 169-178.

Söderström L (1988b) Sequence of bryophytes and lichens in relation to substrate variables of decaying coniferous wood in Northern Sweden. *Nordic Journal of Botany* **8**, 89-97.

Söderström L (1993) Substrate preference in some forest bryophytes: a quantitative study. *Lindbergia* **18**, 98-103.

Söderström L, Hallingback T, Gustafsson L, Cronberg N, Hedenäs L (1992) Bryophyte conservation for the future. *Biological Conservation* **59**, 265-270.

Sokal RR, Rohlf FJ (1995) 'Biometry. The principles and practice of statistics in biological research.' (W.H. Freeman and Company.: New York.)

Southorn ADL (1976) Bryophyte recolonisation of burnt ground with particular reference of *Funaria hygrometrica*. I. Factors affecting the patterns of recolonsiation. *Journal of Bryology* **9**, 63-80.

Specht A, Specht RL (1993) Species richness and canopy productivity of Australian plant communities. *Biodiversity and Conservation* **2**, 152-167.

Specht RL (1970) Vegetation. In 'The Australian environment.' (Ed. GW Leeper.) pp. 44-67. (CSIRO and Melbourne University Press.: Melbourne.)

Spies TA, Franklin JF, Thomas TB (1988) Coarse woody debris in Douglas-fir Forests of western Oregon and Washington. *Ecology* **69**, 1689-1702.

Sturtevant BR, Bissonette JA, Long JN, Roberts DW (1997) Coarse woody debris as a function of age, stand structure, and disturbance in boreal Newfoundland. *Ecological Applications* **7**, 702-712.

ter Braak CJF (1991) CANOCO - a FORTRAN program for Canonical Community Ordination. In. (Microcomputer Power, Ithaca: New York)

ter Braak CJF, Prentice IC (1988) A theory of gradient analysis. *Advances in Ecological Research* **18**, 271-317.

Turner LA (1996) 'Think Habitat.' Department of Natural Resources and Environment, Melbourne.

van Zanten BO, Pócz T (1981) Distribution and dispersal of bryophytes. *Advances in Bryology* **1**, 479-562.

Vane-Wright RI, Humphries CJ, Williams PH (1991) What to protect? - systematics and the agony of choice. *Biological Conservation* **55**, 235-254.

Vellak K, Paal J (1999) Diversity of bryophyte vegetation in some forest types in Estonia: a comparison of old unmanaged and managed forest. *Biodiversity and Conservation* **8**, 1595-1620.

Vitt DH, Chee W-L (1990) The relationships of vegetation to surface water chemistry and peat chemistry in fens of Alberta, Canada. *Vegetatio* **89**, 87-106.

Vitt DH, Li YH, Belland RJ (1995) Patterns of bryophyte diversity in peatlands of continental western Canada. *The Bryologist* **98**, 218-227.

Warcup JH (1981) Effect of fire in the soil microflora and other non-vascular plants. In 'Fire and the Australian biota'. (Eds AM Gill, RH Groves and IR Noble) pp. 203 - 214. (Australian Academy of Science: Canberra)

Wells P, Hickey JE (1999) Wet sclerophyll, mixed and swamp forest. In 'Vegetation of Tasmania'. (Eds JB Reid, RS Hill, MJ Brown and MJ Hovendon) pp. 224-243. (Australian Government Printing Service: Canberra)

Whinam J, Barmuta LA, Chilcott N (2001) Floristic description and environmental relationships of Tasmanian *Sphagnum* communities and their conservation management. *Australian Journal of Botany* **49**, 673-685.

Whinam J, Eberhard S, Kirkpatrick JB, Moscal A (1989) 'Ecology and conservation status of Tasmanian *Sphagnum* peatlands.' (Tasmanian Conservation Trust: Hobart)

Whiteley SB (1999) Calculating the sustainable yield of Tasmania's State Forests. *Tasforests* **11**, 23-34.

Whittle CA, Duchesne LC, Needham T (1997) The impact of broadcast burning and fires severity in species composition and abundance of surface vegetation in a jack pine (*Pinus banksiana*) clear-cut. *Forest Ecology and Management* **94**, 141-148.

Williams WT, Clifford HT (1971) On the comparison of two classifications of the same set of elements. *Taxon* **20**, 519-522.

Wolf JHD (1994) Factors controlling the distribution of vascular and non-vascular epiphytes in the Northern Andes. *Vegetatio* **112**, 15-28.

Wood LJ, Kirkpatrick JB (1984) The allocation of rights to public forest in Tasmania: a geographical critique. *Applied Geography* **4**, 215-223.

Woodgate PW, Peel WD, Ritman KT, Coram JE, Brady A, Rule AJ, Banks JCG (1994) 'A study of old growth forests of East Gippsland.' (Department of Conservation and Natural Resources: Melbourne.)